Modern Manufacture of Portland Cement

Percy C. H. West

THE MODERN MANUFACTURE OF PORTLAND CEMENT

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A Handbook
FOR MANUFACTURERS, USERS, AND ALL INTERESTED IN PORTLAND CEMENT

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VOL. I.—MACHINERY AND KILNS

Containing 159 Illustrations and Numerous Tables

Capio Lumen

NEW YORK
McGRAW-HILL BOOK COMPANY
239 WEST 39TH STREET
LONDON
CROSBY LOCKWOOD AND SON
1910

PREFACE

Few industries have expanded with such rapidity, and few have suffered such great changes in their individual processes, as the manufacture of Portland cement. Yet of all industries, this has perhaps the poorest literature attached to it—at least in the English language. The testing, and of late the uses, of Portland cement have been treated somewhat copiously, but there can be no doubt that the modern process of manufacture has been largely neglected.

The advance towards perfection and the increase in economy have been such that it is no easy matter to obtain an embracing view of the industry without considerable labour. The present volume has been planned to present, in short review, a description of the modern machinery at present employed, and attention has been restricted almost entirely to this the most neglected field.

Every endeavour has been made to refrain from dogmatism. Positive statements not infrequently do harm and often they are untrue. Now it will be declared that the dry process is superior in all cases to the wet, then it will be declared that the wet process is best even for hard raw materials; while at one time it was generally stated that a good cement could not be made by any process other than the wet. The truth lies between the above statements, while each of them in itself is wrong.

At another time it will be stated that the use of the rotary kiln gives the greatest economy in working, and the contradiction made by those who have used it will be that it is the most expensive. A generality of this kind

is obviously untrue; for in one place labour may be very cheap and coal very dear, while at another the conditions may be reversed. But neglecting this, what does the term "rotary kiln" mean? for it includes a kiln anything from 60 to 250 feet in length and from 5 to 10 feet in diameter, and the coal consumption may be in one plant only two-thirds or less of that in another. Those permeated by a hatred of the rotary, and some users of it, will say that the cost of repairs is enormous, but this factor, at least, depends not only on the type of kiln and accessory plant, but upon the way it has been erected, and most of all the men who run or have run it.

It is for considerations such as the above that most statements in this book are not characterised by the positiveness which a number of people prefer.

Thanks are due to the many firms manufacturing machinery who have so greatly assisted the writer by supplying photographs and blocks.

In a separate volume, now in course of preparation, the writer hopes to deal with the chemical and physical testing of the raw materials and finished product and the general control of the manufacturing process. The results of recent research, too, and the scientific side of the subject will be treated at length in this second volume, which will thus provide a review of the state of knowledge of this branch of the subject at the present day.

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London.

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THE MODERN MANUFACTURE OF PORTLAND CEMENT

INTRODUCTORY.

The manufacture of Portland cement has made such enormous strides both with regard to output and methods of production, since its invention by Joseph Aspdin, a bricklayer of Leeds, that it is now one of the most important industrial operations. The increase in output has been greater abroad than in England, and it is equally true that the methods of production have shown a more marked improvement in countries other than that of its origin. For example, the annual output of Great Britain was somewhat over one million tons in 1890, whereas in 1907 it aggregated approximately two and three-quarter million tons. During the same period Germany increased her production from one and a half to five million tons, and the United States from fifty thousand to eight million tons.

Not only has the production increased, but the varieties of raw material employed have increased in number, and their physical characters now vary from a calcareous mud to the hardest limestone, and from the softest argillaceous deposits to the most difficultly ground slate. The chemical composition of the raw materials from which the cement is prepared also vary within wide limits, including not only the practically pure calcareous and argillaceous deposits which were at first employed, but argillaceous limestones, calcareous shales, blast furnace slag, and natural calcium silico-aluminates.

Differing so widely in composition and character as do the raw materials, the composition of Portland cement, derived from various sources, is nevertheless fairly constant. It would, therefore, seem a matter of no great difficulty to arrive at a definition which would be universally accepted, but so far no definition has been thus favoured.

The essential point in the manufacture of Portland cement and the one which differentiates the product from all other cementitious material, is the heating of the raw materials to at least incipient fusion or clinkering, but this is also true of blast furnace slags, which, without subsequent treatment, have feeble hydraulic properties in consequence of their low lime content. It is, therefore, necessary to include in the definition a lower limit for the ratio of lime to soluble silica and other acidic compounds. In the German "Normen" the lower limit adopted is 1·7, and in this way, the passing off of mixtures of slag and Portland cement as pure Portland cement is rendered more difficult, as by a simple analysis it would be quite easy to demonstrate that the product was not of the quality specified, and at the same time a number of badly prepared cements would be excluded from the market. The adoption of a higher value for the minimum ratio of lime to silica and alumina would naturally act more effectively in the same direc ion. The superior limit for this ratio adopted in the earlier editions of the "Normen" was 2·2, but in that published in the past year there is no superior limit. According to the British Standard Specification the ratio of lime to silica plus alumina in equivalents must not exceed 2·85, but so far no cements which are sound even approach this. After burning, only a small percentage of material may be added, and in the British Standard this addition is limited to 2 per cent. of water and 2 of anhydrous calcium sulphate. If the foregoing was accepted as a definition, there would be nothing to prevent a natural rock being quarried and clinkered without previous reduction or mixing, the clinker being ground and then sold as Portland cement. Many deposits are found having a composition very closely approximating to that of an artificial mixture such as is used for the

production of Portland cement, and if it is properly burned, that is, clinkered, and the content of lime is neither so high as to render the cement unsound, nor so low as to render its mechanical strength low, a very good cement is produced. But such deposits usually vary in composition, and a variation of only 2 per cent., or less, in carbonate of lime in the raw material separates a sound from an unsound cement. It has, therefore, become general to embody in specifications for Portland cements the provision that the raw materials must be finely ground and intimately mixed.

The only compounds which are ordinarily present in Portland cement and are considered to have an effect, if present in quantities exceeding a certain limit, detrimental to its quality, are magnesia and sulphuric anhydride. The proportion in which they may exist is limited by the various specifications, and in the case of magnesia, according to the "Normen," it must not exceed 4 per cent.; while the British Standard only allows the presence of 3 per cent. Of sulphuric anhydride, the German "Normen" limits the content to $2\frac{1}{2}$, while the British Standard permits this compound to be present in quantities not exceeding $2\frac{3}{4}$ per cent.

Alumina is generally regarded as a source of weakness if present in quantity exceeding a certain limit, and researches carried out with a view to determine the behaviour of cement under the action of sea water have shown that the expansion which takes place under such circumstances is greater in the case of highly aluminous cements than in those containing a smaller proportion of this compound. At present, however, in the more important specifications at least, no limit is laid down, but upon examining a number of analyses of German, American, and English Portland cements, the ratio of alumina to silica was found not to exceed 0·51, while in the majority it fell considerably below this.

Portland cement may, therefore, be defined as a product prepared by grinding the clinker formed by burning a mixture of calcareous and argillaceous materials, which have been reduced to a sufficient degree of fineness, and have been mixed intimately enough to give a product of uniform com-

position when burned at a temperature sufficiently great to produce at least incipient fusion: the resulting clinker containing lime in a proportion not less than 1·7, nor more than 2·2 times the amount of soluble silica plus alumina and ferric oxide, and containing not more than 4 per cent. of magnesia nor more than 2·75 per cent. of sulphuric anhydride. It is customary to insert a provision in specifications limiting the additions which may be made subsequent to burning; this is calculated to prevent adulteration, but in practice it would appear to be ineffective. The "Normen" limits the addition to 3 per cent., the Danish specification to 2, while the British allows the additions to 2 per cent. of water and 2 per cent. of gypsum for the regulation of the set. Rotary kilns produce a quick-setting cement which without addition contains in many instances little more than 0·2 per cent. of water and carbon dioxide and a similar proportion of sulphuric anhydride; consequently when such additions as are permitted by the British Standard Specification are made, the resulting cements would contain 2·2 per cent. of water and carbon dioxide, and about 2·5 per cent. of gypsum. The cement from a vertical kiln usually contains more both of water and sulphates, and therefore, the limits placed as they are, are inimical to the interests of makers of rotary kiln cement. Sulphates, whether present in the clinker, or added subsequently, are harmful when they exceed a certain figure, and it has not been proven that their effect is more pronouncedly so when added in the proportion of, say, 3 per cent., than when present in the clinker in quantities of over 4½ per cent. as is permitted by the British Standard Specification. With regard to the addition of water, at first sight it seems quite reasonable that the consumer should object to pay for it at the price of cement, but even when it is present in quantity exceeding 3 per cent., it has no effect in reducing the cementitious quality of the cement; nevertheless, many would object to so high a proportion, but would accept a cement without complaint, having a tensile strength 25 per cent. lower than such an "over-watered" brand, more especially if the former were sold under an ancient brand and manufactured by an antiquated firm with similarly aged plant.

In amplification of the above remarks with regard to the composition of Portland cements, the following table showing the upper and lower limits of the constituents of modern Portland cements is given :—

	German.		American.	
Silica	24·04	17·23	23·48	19·06
Insoluble	3·15	0·37	...	...
Alumina	9·08	2·96	10·11	4·12
Ferric oxide	4·62	1·23	5·18	1·61
Lime	67·60	57·72	65·44	58·07
Magnesia	3·57	0·51	3·53	0·25
Sulphuric anhydride	3·30	0·88	2·86	0·25
Water and carbon dioxide	7·32	0·94	...	...

From the above it will be a matter of no great difficulty to calculate from the analysis of a deposit whether it can be employed for the production of Portland cement, but the further consideration of the chemical aspect of this matter will be fully treated of in another chapter : the above considerations only being included here as a necessary preamble to the treatment of the mechanical side of the manufacturing process.

It has been already stated that the physical character of the raw materials vary in a remarkable degree, which leads to the division of the process of winning and preparing the raw materials into two divisions. The harder raw materials are blasted down, while the softer are dug and even pumped. Naturally the two classes merge the one into the other, and the methods of winning and their subsequent preparation, at times, closely approach one another. For example, there are many materials which can be treated with very little difference in economy of power by the dry or by the wet process. And here it may be mentioned that by the wet process is meant the European system of grinding the material without previous drying. The hard raw materials are best treated by the dry process, and although it may be heard that in certain American works the wet process is employed, it is frequently meant that the materials are first

dried and ground and then mixed with water. Indeed, the wet process as understood in America as often as not consists in first dry grinding and them mixing with water, even when a naturally extremely wet material such as marl, which term in America is used to designate fresh-water deposits of alluvial calcium carbonate occurring in that country, is employed.

BOOK I

WET PROCESS

CHAPTER I

WASH-MILLS

In the wet process as carried out in Europe, the raw materials are taken, and, without previous drying, tipped into the mills. The softer varieties, such as chalk and clay, in a country having a heavy annual rainfall, contain a high proportion of moisture, often exceeding 20 per cent. while Medway mud contains over 30. To drive off this quantity of water would necessitate a considerable expenditure of fuel, and modern dry grinding mills are unable to deal economically with material containing more than 2 or 3 per cent. of moisture. Moreover, many materials possess a much lower mechanical strength in their naturally moist condition, and in suitable grinding machinery a smaller consumption of power results from their treatment in this condition. The ideal conditions of the wet process is to prepare the raw mixture with the minimum proportion of water consonant with efficient grinding and mixing, and with certain arrangements of plant, and with soft and homogeneous raw materials this can be obtained with a proportion of water no greater than 25 per cent. Materials which can be satisfactorily worked in this condition are few, and the product obtained cannot be transported in bulk, but must be briquetted and dried, in which condition it can be burnt only in the ring kiln or in some form of shaft kiln. For such treatment roller-mills and pug-mills are employed, but an interesting variant of this system may be described. In the first Portland cement works to be erected

in Germany, the chalk was washed in a wash-mill with the addition of water, the product was then allowed to settle, and after the water was run off, the chalk paste was dredged from the backs and then spread in a thin layer, the requisite proportion of finely ground clay was added, the whole being mixed and briquetted in accordance with the usual plastic brick-making system.

The quantity of water which must be contained in a slurry so as to render it sufficiently fluid to be conveyed with ease and to render it easily treated both from the point of view of grinding and mixing is from 35 to 45 per cent. For the preparation of such a product, the wash-mill is most commonly used, and it is undoubtedly the most efficient mill for the preliminary reduction of the softer varieties of raw material. It is also the oldest type of mill employed in the modern cement works, it having suffered only minor alterations in its details while its contemporaries have been entirely supplanted.

According to design, wash-mills may be divided into two classes: the one in which the tines are held in a frame rigidly secured to a vertical shaft, and the other in which they are arranged in harrow frames suspended by chains from arms which are secured to the shaft.

Mills of the latter class in one or other of their modifications are more employed, as a class, than are those of the former.

In Fig. 1 a recent design is shown in sectional elevation and plan.

The pit in which the harrows revolve is of brickwork or concrete, and in its centre is provided a short pier to which is secured the footstep bearing of the vertical shaft. This is supported by a neck bearing near its upper end, and is rotated by a pair of bevel wheels. A short distance above the footstep a casting is secured, which holds the arms, in position. At their outer extremities these bars are joined by means of tie-rods, rendering the arrangement more rigid. Two rows of double hooks are secured to the arms which, by means of chains, support the harrow frames. These are of cast iron or cast steel, and are provided with eyebolts to

which the chains are secured, and at their outer and inner extremities they are provided with perforated lugs by means of which the distance rods are secured with the aid of pins. Gratings through which the slurry, as the mixture of raw material and water is called, passes are arranged at intervals

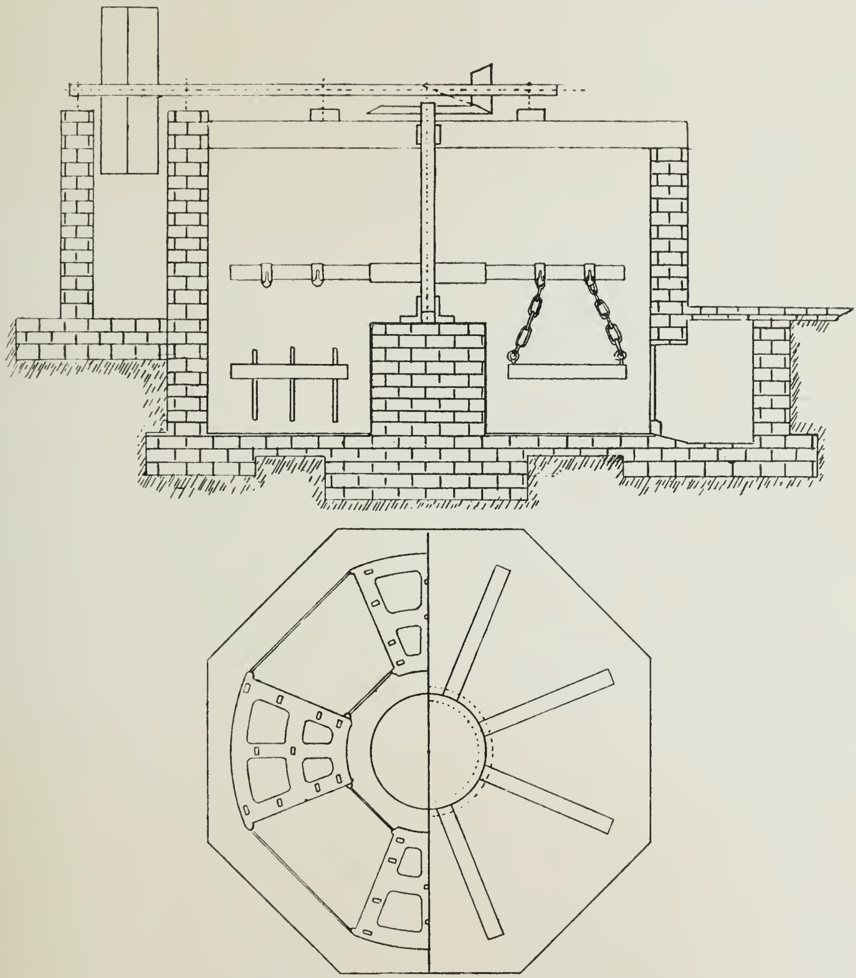

Fig. 1.—Wash-Mill with Chain suspended Harrows.

round the periphery of the pit. The square bars used in the mill just described are sometimes replaced by bars of T section secured in a similar way; these are usually stayed by means of rods extending from their outer extremity to a collar fixed a little below the neck bearing.

Another design of suspension frame consists of a pair of channel bars secured together and crossing another pair similarly secured. From this frame the harrow frames are supported by means of chains.

The speed at which the harrows in this class of wash-mill is rotated has increased of recent years, and they are consequently built of greater strength than formerly. In a mill having a diameter of 15 feet, a very general size, the harrows

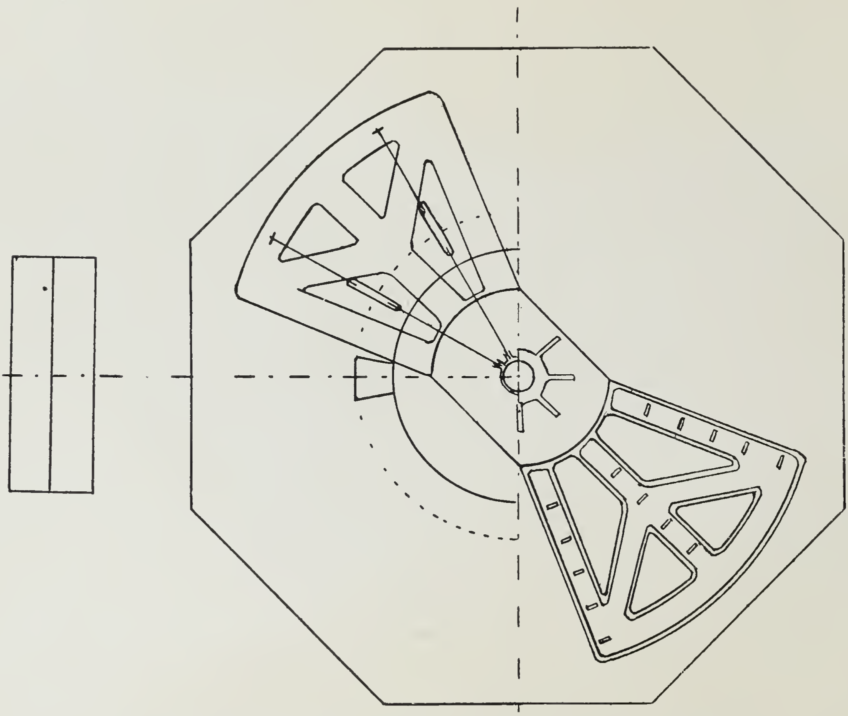

Fig. 2.—Wash-Mill with Harrow Frames secured to Shaft.

are rotated at a speed of 24 revolutions per minute. In the case of smaller mills, the angular velocity is greater, but the peripheral speed approximates 1,000 feet per minute.

Another type of wash-mill in which the tines are held in frames secured to the driving shaft is shown in Fig. 2. The frames in this mill are shaped like the harrows of the wash-mills shown in Fig. 1, and they are set with a number of tines in a similar way. The chain suspension of the harrow frames presents numerous obvious advantages over the rigid

suspension system, and is more commonly used. Its flexibility serves to protect from breakage the toothed wheels by which the vertical shaft is driven, and, when starting, the strain caused by the setting of the slurry in the mill is much reduced.

The material of which the harrow frames are constructed is cast steel or tough cast iron. The latter is sufficiently strong if the frames are well proportioned, but the use of cast steel is to be recommended, especially where the raw materials are fed in large pieces to the mill, or if it is hard or contains a large quantity of flints.

The footstep bearing is, with advantage, arranged in a box provided with centring screws, and supported on a wedge block which can be used for slightly raising or lowering the shaft. With this arrangement it is possible to remove the footstep altogether by first putting some packing beneath the crown wheel, and then withdrawing the wedge block.

The tines are secured in the harrow frame either by screwing their upper ends and passing them through the holes provided in the frame and securing them by means of nuts, or by drilling a series of holes in the tine, passing it through the hole in the harrow frame and securing it in position by means of a bolt or pin. This latter arrangement is the more usually adopted in modern plants, as in this way the tine, as it wears, may be lowered. In addition to this, the tines can be made much stronger; in some cases they are of manganese steel of 3 inches by $3\frac{1}{2}$ inches section.

The pits in which the harrows revolve are either circular or octagonal in plan, and of the two forms, the latter is the better, as this shape leads to the formation of eddy currents, and the material is thus prevented from being driven round *en masse*, and the grinding effect is therefore greater. As has already been stated, the pits are constructed of brick or concrete; in both cases, and more especially in the latter, it is advisable to line and pave them with chilled iron plates or hard stone, the bottoms and sides being subject to considerable wear, more particularly so, when flinty chalk is one of the materials employed.

The gratings of wash-mills are situated at convenient distances around the periphery of the pit, and the material

washed through them passes into a trough communicating with the plant used for further treating the slurry. The number of gratings in a mill varies, and may be as high as four or as low as one, and their area and method of construction also varies. They usually have the section shown in Fig. 3, and it may be here noticed that it is advisable to set them so that the narrow side of the slit is towards the wash-mill, as when placed in the reverse way, which is not infrequently done, the slits clog more easily, large pieces becoming jammed between the converging sides of the bars. Arranging the grid so that the slits are horizontal is also better than placing them vertically, as the wash of the material tends to clear out any pieces which have been caught in them. The water is run into the mill through a pipe discharging either into the centre of the mill from above, or projecting through the side wall of the mill. In this

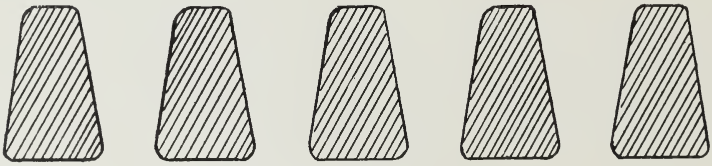

Fig. 3.—Section of Wash-Mill Grating.

latter case it is scarcely necessary to remark that the pipe should discharge some distance from a grating, and in the direction of rotation of the harrows. The chalk and clay are charged into the mill most usually from skips or tipping waggons, which should be loaded and run over a weighbridge and there adjusted to a definite weight. It is a generally adopted convention that the weight of the chalk or more calcareous materials is kept constant, and that the weight of the clay is varied when necessary to accommodate varying degrees of humidity of the materials, or when it is desired to raise or lower the proportion of calcium carbonate in the slurry.

Slurries may be divided into two classes, those which contain about 40 per cent. of water, and those which contain about 80 per cent. When the former percentage is worked, the process is sometimes called the semi-wet, and is due to

Goreham, while the latter is the "wet" process as originally employed on the banks of the Thames and Medway and elsewhere. However, it has become the custom to group the two systems together under the description which, upon historic grounds, belongs to the older, and at the present day, the term wet process more often refers to the former than to the latter. With thin slurries containing about 80 per cent. of water, the wash-mills discharged over an outlet, the height of which could be adjusted, and the slurry was run into backs to settle, the water being drained off at intervals. The butter-like mass obtained in this way was dug out and loaded on to the drying flats, but this system has been superseded even in works using old-fashioned kilns. The Portland-Cement Fabrik "Stern" at Stettin still wash with this large excess of water, and after allowing the slurry to settle, the material containing about 40 per cent of water is excavated, and conveyed to a mixer from which it is fed into the rotary kilns.

The advantage which such thin slurries possess over the thicker mixtures is that large particles settle from them more easily and catch-pits are more effective. In addition, the slurry deposits any large particles which have been carried along and deposits them under outlets of the pipes and at the bottom of the backs, and a finer slurry is thus obtained without the employment of additional grinding plant. But the disadvantages of the system are somewhat pronounced. If it is adopted, a large area has to be covered with backs, and the labour consequent on transferring the partially dried material to the flats or to the mixers is considerable. This process, as we have said, is therefore rarely employed.

Most frequently the chalk and clay are tipped into the same wash-mill, but in certain cases, separate mills are used for the two raw materials, notably when one of the materials is considerably harder than the other. In such cases, the harder material is frequently coarsely ground in an altogether different type of mill, such as a wet edge-runner or a sieveless ball-mill, but if wash-mills are employed for its reduction, the more easily ground, in practice the argillaceous, material is washed in one mill, and then run into the other into which

the harder material with or without previous grinding is fed. The slurry then passes into another wash-mill fitted with finer gratings, after passing which it is finished, that is, ground to what is deemed a sufficiently fine product in a mill of another type.

In the arrangement that has just been mentioned, it will be observed that three wash-mills are employed for grinding the slurry. Frequently with soft material such a number or even four are used, the chalk and clay being tipped into the first of the series from which the slurry passes in succession through the others, each successive mill being furnished with finer gratings than its predecessors. The slurry, as it comes from the wash-mills, is rarely sufficiently fine to pass without further treatment, to the kilns, especially if prepared from a practically pure limestone and a clay; for small nibs of calcium carbonate such as would be retained on the 50 or even 30 mesh sieve are contained in it owing to the relative coarseness of the gratings. These nibs burn and leave specks of lime in the clinker, which when ground, would produce an unsound cement, needing aeration. Aeration is quite opposed to the trend of modern practice, and as the unsoundness may also be due to the slurry containing too high a percentage of lime, it would therefore be a matter of doubt as to which was the cause in a particular instance. Moreover, the finer the slurry is ground and the more intimate the mixture of the materials, the higher in lime may be the clinker and the better will be the tests of the cement. It has, therefore, become a general practice to further treat the slurry so as to eliminate these coarse particles, for which purpose mills of another type are employed.

Although the nibs of limestone are the most objectionable from the chemical point of view, some raw materials such as the upper chalk contain flint, nibs of which are a nearly equal source of annoyance, scoring the rams of ram pumps or breaking the chains of chain pumps, and consequently it is of equal importance to separate them from the slurry. To a certain extent, catch-pits have this result, but usually their effect is not sufficiently marked, and some other device has to be employed for the removal of these sources of inconvenience.

CHAPTER II

WET EDGE-RUNNERS AND STONE-MILLS

It has already been stated that when one of the raw materials is considerably harder than the other, the hard material is ground in a separate wash-mill, or by means of a mill of an entirely different type. Of course, if both materials are too hard to be conveniently ground in a wash-mill, and for some reason the wet process is decided upon, it is necessary to treat both in mills more capable of dealing with them. One of the earliest designs of mill, if not the earliest, adopted for this is the wet edge-runner, of which an illustration is given in Fig. 4.

The pit in which the rolls run is constructed of brick or concrete, and the bottom is laid with chilled cast-iron plates. To the vertical shaft, journalled in a footstep and a neck bearing, a casting is keyed into which two cranks are fitted, on the pins of which, two heavy cast-iron bosses are secured. These bosses are provided with chilled iron or manganese steel tyres secured to them by means of bolts. The cranks permit of independent vertical motion to the runners, thus avoiding the necessity of both runners rising when one of them passes over a large and refractory lump; in this way, strains on the vertical shaft are diminished. The material to be ground is dumped into the pit, and the requisite amount of water added. Scrapers are provided both on the rolls and on the grinding plates so as to remove material adhering to them. The rotation of the vertical shaft causes the rolls and rakes to travel round the pit, and the materials are thus crushed and mixed with the water. The slurry discharges through coarse grids at a certain height above the bottom of the pit. The power required for a given output with a wet edge-runner is greater than that consumed by a wash-mill, having a similar output on raw materials having the hard-

ness of ordinary chalk or clay; they are therefore not so well suited for grinding these materials, and their use should therefore be restricted to materials of a harder nature. It may be added that the wet-edge runner has not met with wide adoption, and at the present day for hard material treated by the wet process it possesses a formidable opponent in the wet ball-mill.

Ball-mills have been for many years employed for dry

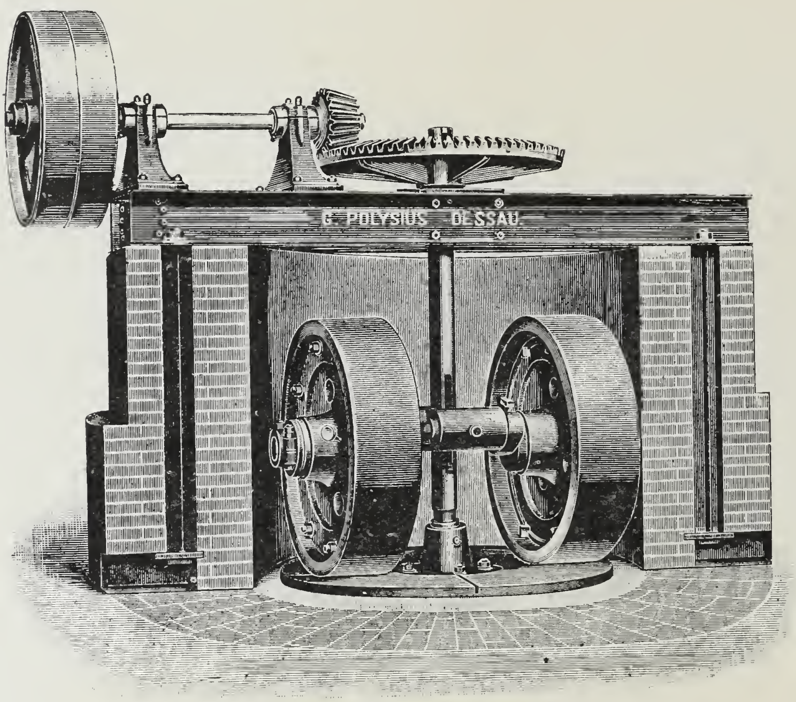

Fig. 4.—Wet Edge-Runner.

grinding, but as usually constructed they are provided with sieves, and are thus absolutely useless for grinding any moist or wet material owing to the clogging of these screens. Without sieves, the ball-mill as designed by certain manufacturers may be used for the preliminary reduction of wet material. Those mills which discharge through holes in the grinding plates and with returns through grids arranged the whole width of the drum are useless for this purpose, unless the grinding plates are without holes and the grids are replaced

by plates having only one fairly large opening at the end opposite the feed side. It is not within the author's knowledge that such a rebuilt mill has yet been employed, but that the plan is feasible will appear from the description of a wet ball-mill which is now in operation. It is known as the "Wet Kominor" and is manufactured by Messrs Smidth.

Keyed to a shaft at a certain distance apart are two naves or hubs, the one blank and the other a spider. To these naves the side plates of wrought iron are secured, and to them is secured a drum formed by bending and riveting a wrought-iron plate. In the side plate, opposite to the feed

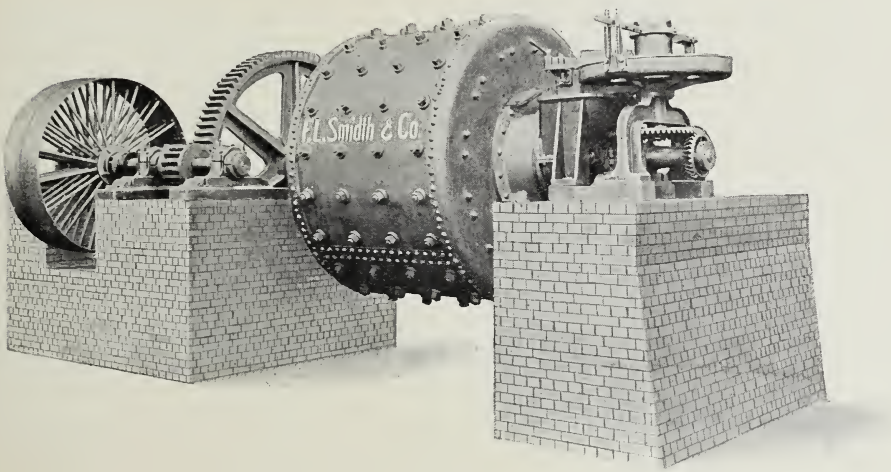

Fig. 5.—Wet Kominor.

table, a number of openings are provided, through which the coarsely ground material passes. The mill is lined with especially tough cast-steel plates, those secured to the drum being arranged so as to form a series of steps. The grinding is performed by a number of forged steel balls, rolling and falling from step to step as the drum is rotated. The material is fed in its naturally moist condition to the drum, and the required amount of water added.

Another type of ball-mill which has been introduced for wet grinding was patented by Ferraris, and therefore a description of it may be of value.

It consists of a drum lined with tough steel plates which

are cast with a projecting ridge that extends the whole width of the drum. The drum has secured to its periphery two tyres and a sectional rack, the tyres bear upon friction rollers and the rack engages with a spur wheel. The mill is charged with a particular weight of balls, and the material to be ground is fed into one end and discharges at the other through a ring formed of slotted steel plate.

The foregoing machines are adapted to coarse grinding, and their product needs further treatment in order to render it suitable for the manufacture of cement. They, therefore, correspond to the wash-mill as it is most frequently employed. The mills employed to complete the reduction of the slurry to the necessary degree of fineness are those in which the grinding is performed between two rotating stones and those in which it is accomplished by the percussive action of falling balls. The former, the millstone, was first adopted. It is one of the oldest forms of mill, and was extensively employed in cement works for grinding clinker at the time that the semi-wet process came into use. It was the adoption of this system of grinding the raw materials together with the increasing demand for higher qualities in the cement which led to the employment of mills for finishing the slurry.

Millstones may be divided into two classes, the one in which the upper stone is the runner, the lower being rigidly secured to the bedplate, and the other in which the upper stone is fixed and the lower rotated. The former is the older type, and is constructed by a number of firms, their designs differ only in details, and as it is now somewhat out of date, in that they are employed only at such works where they were installed many years ago, only one example will be described. In Fig. 6 the bedstone is secured to the bedplate, supported on strong cast-iron columns of any convenient section. The upper stone or runner is thicker and therefore heavier either on account of its thickness or by reason of a backing of concrete in which lumps of scrap iron are often embedded. It is carried on the cockhead which is secured to a vertical shaft passing through a neck bearing in the bedplate and supported by a footstep bearing

secured either to the sole plate or to the bridge piece. This footstep bearing is adjustable so as to render it possible to increase or diminish the distance between the stones. In the mill illustrated in the following figure, the adjusting mechanism is operated by means of a worm and worm wheel

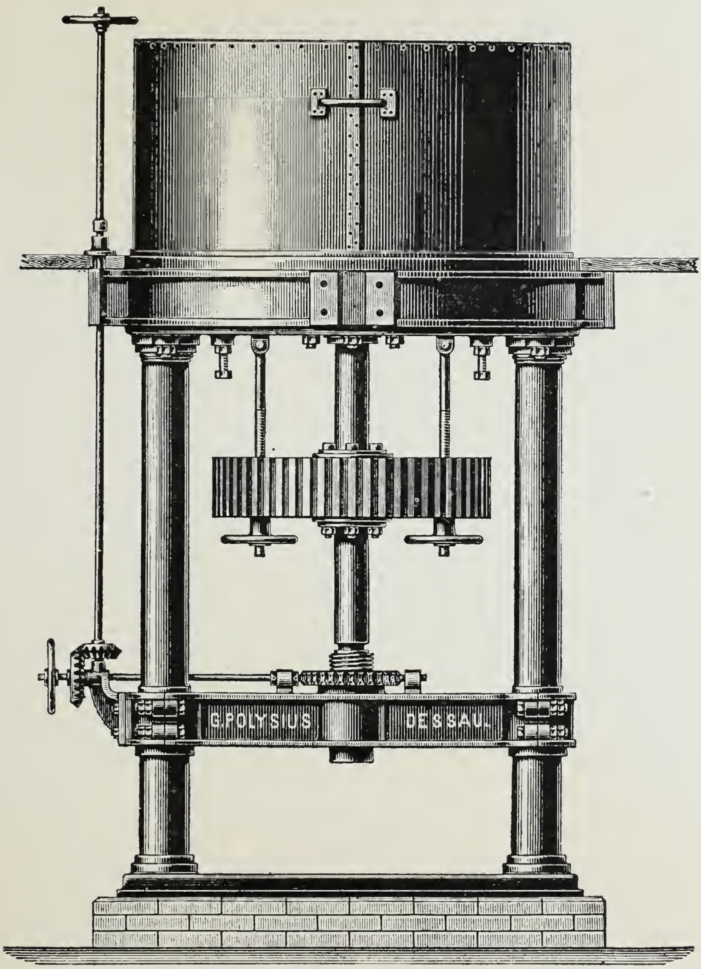

Fig. 6.—Upper Runner Millstone.

which, through bevel gearing and a hand wheel, permits of the adjustment being made from the mill floor. The runner is driven by means of bevel gearing from a lay shaft which is usually arranged to drive a whole series of these mills. The hursts are bolted together so that they

form together a compact and stable arrangement, the mill floor being on a level with the bedplates. When a number of these mills are employed, and it is essential to have more than one to avoid interruption of grinding when the wear on a particular mill necessitates redressing the stones, it is convenient to have each mill provided with a clutch so that any of them may be stopped without stopping the whole row. As usually arranged, clutches are not employed, and when it is required to put a mill out of operation, the whole of them are stopped and the spur or bevel wheel on the vertical shaft is raised by means of the hand wheels which can be seen in the illustration. With stone mills the dressing of the stones is a source of expense, but this is not so pronounced with wet stones as with dry; nor, naturally, with soft material as with hard. This has led to the employment of rock emery in place of burrstone for the face, a system which was patented by Messrs Addison, Potter, & Co. of Newcastle-on-Tyne, and to a modern application of which we shall refer later.

For the handling of the upper stone in dressing, hand-operated stone cranes should be provided at convenient points. They usually take the form of jibs secured to one of the members of the mill house structure.

The newer or under runner type of stone-mill differs not only in its operation but in the whole system of construction. They are more compact machines, and their operation is better in many ways.

The upper stone is fixed by means of set screws in a cast-iron casing, which is held down by means of volute buffer springs to the lower section of the casing provided with an outlet which is supported on a cast-iron frame. The runner is secured to a cast-iron disc provided with ribs on its under side, and this disc is carried and revolved by the vertical shaft, which is journalled in a dust-tight neck bearing in the pan and a footstep bearing bolted to the sole plate. The distance between the stones is regulated by means of a worm and worm wheel operated by bevel gearing and hand wheel. The material to be ground is fed in the usual manner through a hole in the top of the casing and falling on to the rotating

stone, is driven outward and distributed over the grinding surface. In upper runner mills, the material remains in the swallow until it is drawn on to the skirt by the runner, and it is in consequence of this difference in distribution that the under runner mills have a greater output in proportion to the power consumed. The running is also more even, and the damage caused by very hard pieces, often accidentally introduced, getting between the stones is much less and is often altogether avoided because

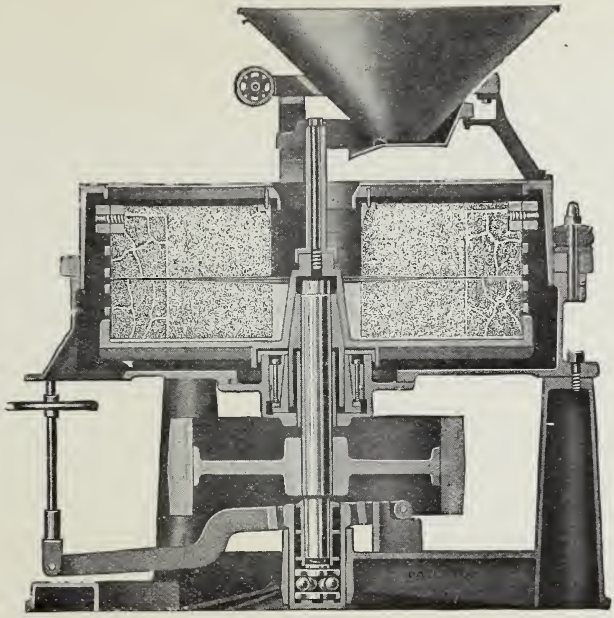

Fig. 7.—Section of Sturtevant Rock Emery and Burrstone Mill.

the upper stone in its casing is raised, while the tension due to the springs is quite sufficient to keep the stones at their proper working distance. The speed at which wet millstones are run is one-half that at which dry stones are driven, and the power consumed per mill is correspondingly less.

The leading dimensions and particulars of both upper and under runner mills is tabulated below. The outputs of course vary as the hardness of the material to be ground and the fineness of the product.

Leading Particulars of Millstones (Wet).

Diameter of stones - - -	3 ft. 3 in.	4 ft.	5 ft.
Revolutions of stones per minute	90	70	55
Power, upper runner - - -	6 H.P.	10 H.P.	15 H.P.
Power, under runner - - -	4 H.P.	6 H.P.	12 H.P.
Output, upper runner - -	6 cwt.	9 cwt.	14 cwt.
Output, under runner - -	9 cwt.	15 cwt.	24 cwt.

The composite rock emery and burrstone has been adopted by one firm as a feature of their mills. A section of one of them is given in Fig. 7, from which the design of the mill can be easily seen. In the main it is similar to the under runner mill just described, but a few of its features are worthy of remark. The vertical shaft is supported at its foot by balls, thus reducing friction to a minimum, and it is rotated not by means of wheels, but by a pulley driven by a half cross belt with or without idlers, depending upon whether the line shaft is approximately in a horizontal plane with the middle of the pulley or at a higher or lower level.

Mention may be made that in certain mills chilled iron facings for the stones are sometimes employed, but the author is not aware of any works in this country which has adopted this system.

CHAPTER III

WET TUBE-MILLS

For a number of years a rotatable drum containing a number of balls has been in use for grinding materials of different kinds. The material to be ground is fed into the drum of this mill through an opening in its side, the cover is then replaced and the mill rotated. After a certain time the cover is removed and replaced by a grid, and by a few more revolutions the ground material is discharged. The fineness to which the material is reduced depends upon its hardness, the weight and number of balls contained in the drum, and the time during which the machine has been rotated. The speed of rotation has also a marked influence upon the efficiency of the mill, and for reasons that will be rendered apparent at a later stage.

It will be seen that in this form the pebble mill has very serious limitations; its intermittent action rendering it valueless for grinding large quantities of materials. A continuous grinder of this class was therefore sought, as the earlier type had shown itself to be an eminently suitable machine for the production of very fine powders. The Davidsen tube-mill was the first continuous mill which came into general use, although a mill of similar design had been devised and employed by the firm of Narjes & Bender some years earlier. As originally designed, it was intended for dry grinding. It consisted of a long rotatable tube, into one end of which the material to be ground was fed, and at the opposite end the ground material was discharged through ports arranged round the periphery.

The shell of the tube-mill consists of a cylinder formed by bending a wrought-iron plate and welding the two edges thus brought together. In certain cases the edges are butt riveted instead of welded, while certain engineers have built up tube-

mills from a number of plates instead of one, riveting the edges, a system which is, however, rarely employed, and even in cases where it is desired to construct the mill in sections for ease and cheapness in transport, it has been almost supplanted by another system ; the shell being built up from a number of long channels of the section shown on Fig. 8, the flanges being riveted. The ends of the tube show a similar variation in design. They are formed of domed shaped steel castings with which the trunnions are cast in one piece, or they are cast flat in one piece with the trunnion, a

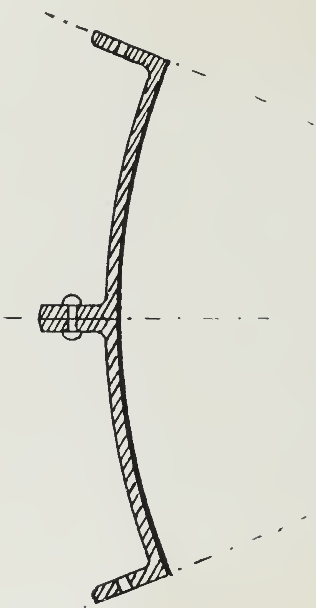

Fig. 8.—Plates for Building up Sectionalised Tube-Mill.

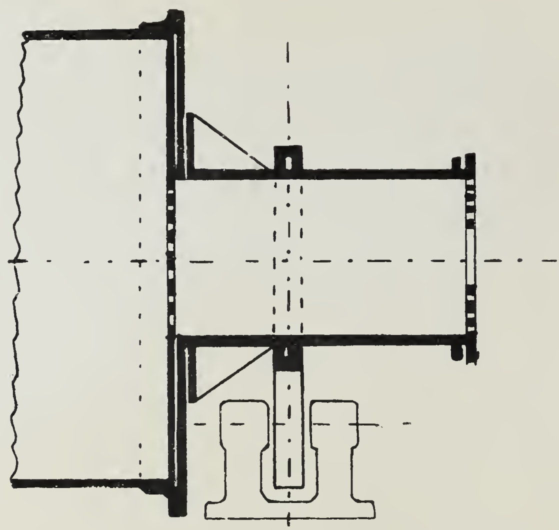

Fig. 9.—Discharge End of Krupp (Steel Ball) Tube-Mill for Wet Grinding.

number of webs, extending from it nearly to the periphery, serving to increase the strength. One firm construct the ends of their mills from wrought-iron plate to which flanged trunnions are secured. The greater number of firms constructing these mills for wet grinding employ plates of similar design both for the feed and the discharge, but Messrs Krupp in certain cases employ a different arrangement shown in Fig. 9, the outlet trunnion of which bears upon two friction rollers.

The tube is rotated in most cases by a split spur gear and

pinion, but recently other systems have been adopted, one of which is the Lenix drive. With this system a tyre is secured to the tube and a belt passes over this and the small pulley on the driving shaft; by means of a weighted jockey pulley the belt is made to wrap round nearly three-quarters of its surface, instead of touching such a small portion of its rim as

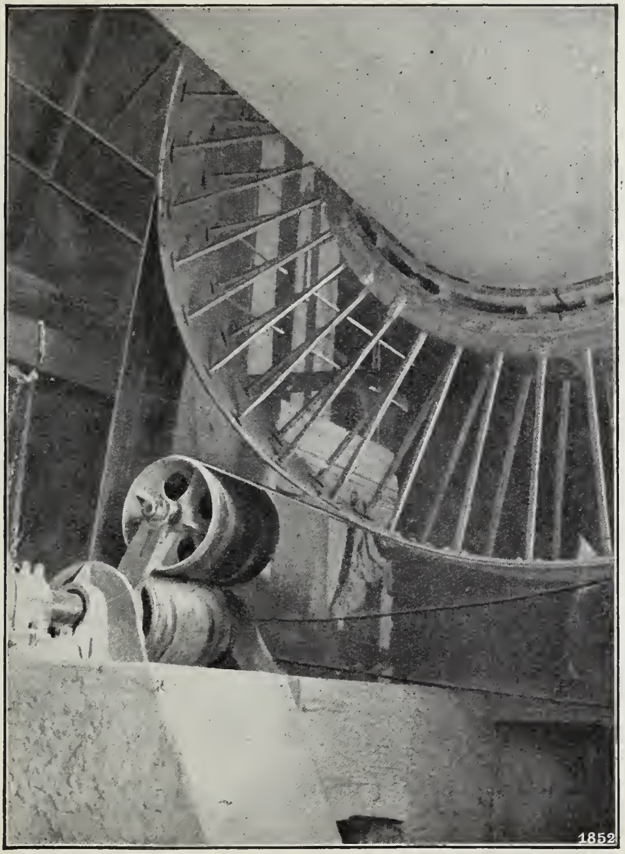

Fig. 10.—Lenix Drive applied to Tube-Mill.

would be the case with a drive at such short centres under ordinary circumstances.

The tube is lined with chilled iron plates secured to the shell by bolts or by means of silex or quartzite blocks set in Portland cement in the case of wet mills.

The mill is filled to about its centre line with rounded flints or with a smaller volume of forged steel balls,

in which case the tube-mill is lined with chilled cast-iron plates.

The slurry is fed into the mill by means of an elbow-shaped casting, one end of which is inserted into the trunnion while the other is secured to the slurry pipe or chute. No worm or other feeding mechanism is required.

After travelling the whole length of the tube as a rule, it is discharged through the trunnion situated at the opposite end of the mill. To prevent the stones or balls from passing out of the mill a grating is secured across the tube at the outlet end, or a circular diaphragm provided with ports situated near its circumference is employed and the slurry is brought from these openings to the trunnion. The type of discharge adopted by Krupp has already been illustrated. The design employed in the wet tube-mills of Polysius is similar to that adopted in the dry mills of the same manufacturer.

Occasionally tube-mills with peripheral discharge are employed for wet grinding, but unless run down, that is—unless the mill is run without feed for a short time before stopping—the coarse slurry contained in the mill will run into the storage tanks.

The tube-mill absorbs a considerable amount of power for driving, and when working upon a slurry prepared from soft raw materials in a wash-mill it does not appear to its greatest advantage. With chalk and clay, the treatment in wash-mills provided with suitably dimensioned gratings produces a product of which at least 80 per cent. passes the 180 mesh sieve, the remainder being in a very fine state of division. This is, of course, not fine enough, but the removal of the relatively small percentage of nibs is an expensive matter when a tube-mill is employed. With the harder raw materials treated by the wet process in ball-mills and similar plant, only a small proportion of fine flour is produced, and in such cases the tube-mill exhibits itself in a much better light.

The following figures are typical of the results obtained on a slurry prepared from chalk and clay, and they clearly

show the greater effect of the tube-mill on the coarser particles :—

Sieve -	180	120	100	76	50	30	20
W. mill -	16·0	10·60	8·40	6·86	5·5	3·4	2·24
Tube -	7·2	4·41	3·17	2·24	1·3	0·46	0·20

The speed at which the tube is rotated is such that the greatest grinding effect is obtained for a given consumption of power; this is conditioned by the number of balls raised in a given moment, the height from which they fall and their specific gravity: for the action of the balls in a tube-mill depends upon percussion and not upon attrition. The speed, therefore, is regulated so that the greatest possible number of balls are raised to the highest point of the mill from which they fall. The character of the surface of the lining, and to a lesser extent of the balls, has therefore a certain influence upon the speed of rotation.

Fischer conducted a number of experiments, the object of which was to determine the mode of operation of the mill and to discover the speed at which it should be rotated. For this purpose a mill was provided with a grating at one end so that the appearance of the interior could be examined.

He found that with an iron-lined mill 39 inches in diameter when rotated at 55 revolutions per minute the balls were evenly distributed round the interior surface of the mill, while at 30 revolutions per minute the balls remained at the bottom and being drawn but little in the direction of rotation. At a speed intermediate between these he found that the greater number of balls were raised to the top of the mill from which point they fall, and it was at this speed that the greatest grinding effect was obtained.

H. A. White attacked the question from the mathematical standpoint arriving at the conclusion that the correct speed lay between that which would cause the balls to fall through a parabola of between 30 deg. and 90 deg. In the latter case the balls would form a practically continuous lining while at the former the balls would not be raised to the greatest possible height.

The following table is abstracted from the paper containing his results :—

Tube half full of stones.
D = diameter at the centre of ball path (not diameter of tube).
N = revolutions per minute.

D. Inches.	N. All continuous.	N. 90°	N. 45°	N. 41°
1	297·8	265	223	214·7
10	...	77·12	...	...
15	76·87	68·44	57·55	55·44
21	64·99	57·84	48·64	46·85
24	60·80	54·1	45·5	43·80
30	54·37	48·39	40·69	39·80
39	47·69	42·44	35·69	34·38
51	41·7	37·11	31·21	30·06
60	38·45	34·22	28·7	27·7

The tube-mill as usually employed in the wet mill is a machine for finishing the product of a coarse grinding-mill; while in dry grinding it is now quite usual to employ a short tube-mill, the so-called "pre-grit mill," for producing a grit-like product. The extension of the wet grinding system to the treatment of hard raw materials, which only a few years since would have been treated by the dry process, has resulted in the adoption of mills for wet grinding of a type closely resembling those used for dry grinding. An example of this is the wet ball-mill, to which reference has already been made.

The latest mill introduced for wet grinding is substantially a "pre-grit mill," that is, a short tube-mill, and it is employed for producing a coarsely ground product which is afterward treated in a finishing mill. The length of the drum instead of being four to five times its diameter, as would be the case in a finishing mill, is only three times as great. A machine of this type is illustrated in the plate facing this page.

It consists of a welded wrought-iron tube to which cast-steel ends are secured. The inlet end is conical in form, and steel rolling rings are secured to it, and to the outlet end. These rolling rings run on rollers secured to spindles, journalled in self-oiling bearings, and a check-roll is provided.

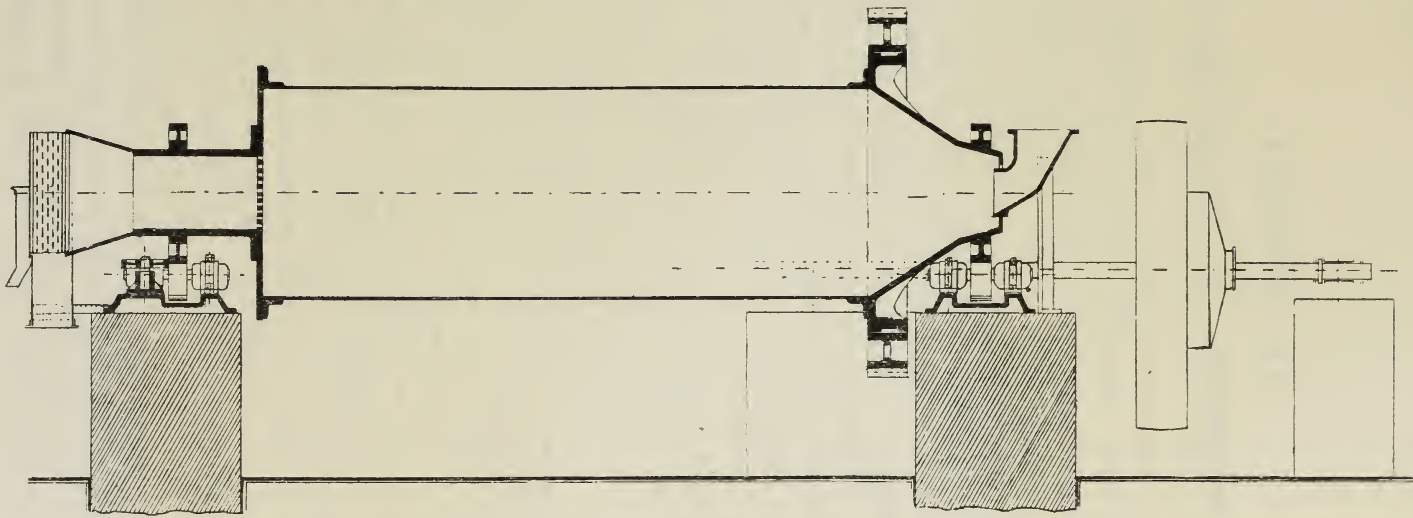

Fig. 11.—Pre-Grit Mill for Wet Grinding.

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CHAPTER IV

OTHER WET MILLS AND ACCESSORY PLANT

The mills employed for finishing the slurry which have been described in the previous chapters naturally raise the cost of manufacture, but at the same time they improve the character of the product. The re-dressing of the stones with millstones is a constantly recurring expense, and although the cost and upkeep of a tube-mill is very low, the occasional addition of stones or steel balls or repairs to the lining being the only renewals which are required at anything but rare intervals, the power it consumes is considerable. Moreover, to both classes of machine there is the objection that the chips of flint from flinty chalk are not reduced to any notable extent, and much less in the case of the tube than in the stone-mills. As stated previously, these chips of flint have a very injurious effect upon pumps. There can, however, be no doubt but that in both cases the nibs of chalk entering the mill are considerably reduced in size.

A series of wash-mills is employed in several works so as to eliminate the necessity for the employment of a special finishing mill, and in other cases some type of sieve is used for a similar end. It is, of course, quite obvious that the power consumed by a sifting machine would be relatively low as compared with an additional grinding-mill. The difficulties in the way of sifting a thick slurry are, however, considerable, as the mass clogs the sieves unless the holes are rather large, in which case they would be valueless.

Faija in 1883 patented a rotating screen, but the machine did not come into general use.

The sifting drum was clothed with a wire or slotted steel sieve and was rotated at a considerable speed, while a tapping or brushing gear was used for removing such large pieces as might adhere to the sieve, the coarse particles being dis-

charged by one chute while the fine slurry passing through the sieves is discharged by another. This machine does not seem to have been employed to any extent in cement works, as the patent was abandoned after the four year period. A sifting device which was introduced about the same time and patented by W. G. Margetts was employed at the West Kent Cement Works in place of stones, and it is stated that the results obtained by its use were very favourable. It consists of a rotating sieve of approximately the form of an inverted cone. The coarser particles were driven upward and over the edge of the sieve and were caught in an annular channel in which scrapers secured to the rotating sieve frame revolved, collecting the coarse particles, and discharging them through a chute leading back to the wash-mill. The results obtained by this machine are favourably spoken of, but it must be remembered that in spite of them the more expensive and power-consuming finishing mills came into general application, so that there can be little doubt that their advantages were more imaginary than real. It will be seen that in both these machines the rotatory motion was imparted to the slurry by the sieve, a somewhat imperfect system. The rotary screens, with a nearly horizontal axis, which had been used in certain cases for treating thin slurry, were not so successful when operating on thick slurry now usually produced, the viscosity of which necessitates the employment of some means for driving it through the perforations. A number of cement manufacturers have constructed machines of their own design. Many of these machines consist of a cylindrical body or drum clothed with slotted plate or gauze, and arranged vertically. Inside this drum some arrangement, in one case a shaft to which blades are secured, like a fan rotor, is provided for driving the slurry through the screens. Around this chamber an annular channel is provided for collecting the slurry.

The "Clarke's Mill" is a sifting device which has within the last two years been adopted in a number of works. In this machine, the rotatory motion is imparted to the slurry by the rotation of a circular brush secured to an iron plate, which is revolved at a high speed. By this means a much better centrifuging action is obtained than when the sieve

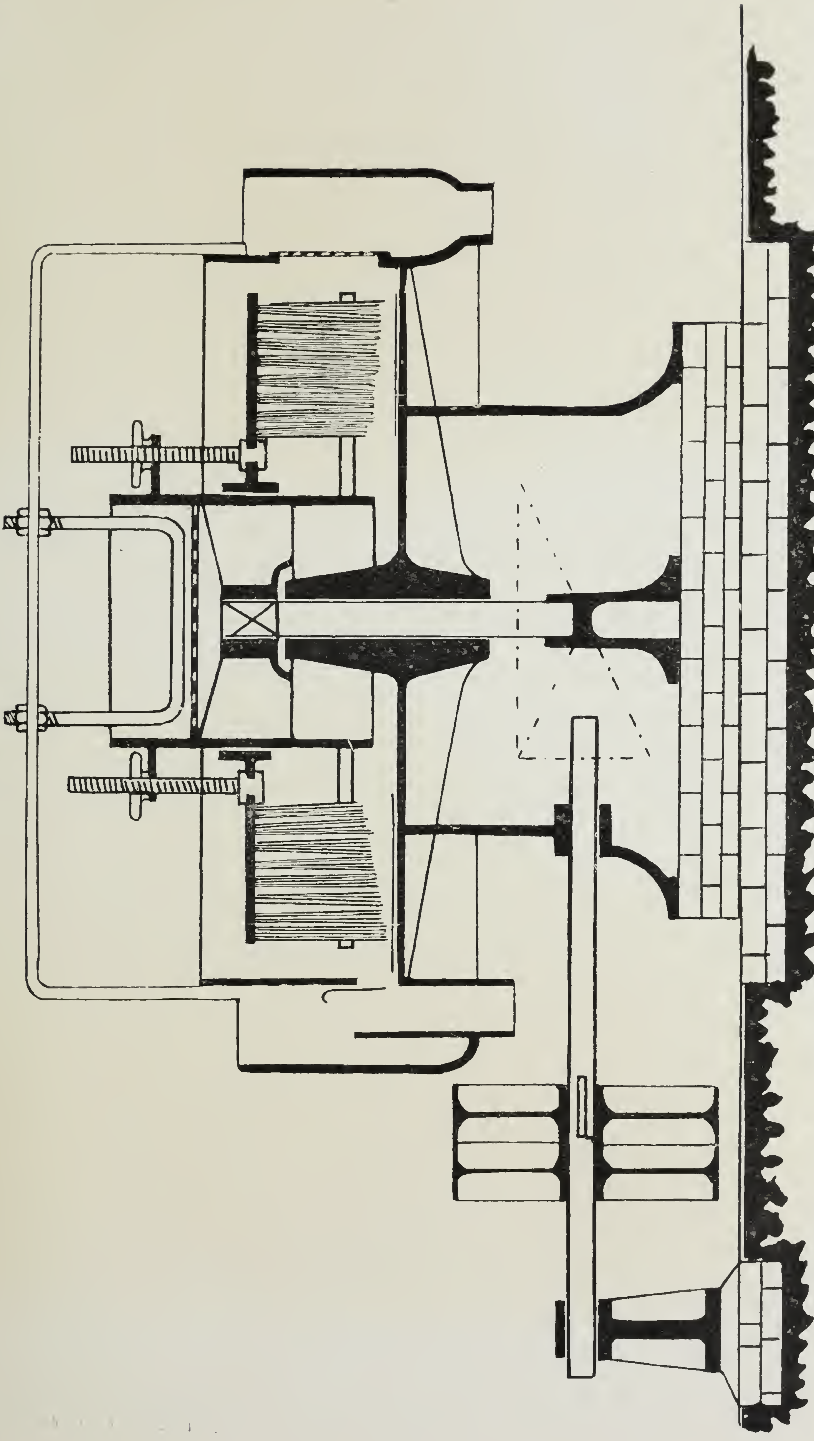


Fig. 12.—Section of "Clarke's" Mill.

itself is rotated, and at the same time the coarse particles are more effectually removed from the sieve.

The slurry is fed into the mill at the centre, where there is a cylinder secured to the driving shaft, and at a certain height a perforated iron plate is provided, which prevents the entry of large pieces. The slurry passes down into the basin in which the brush secured to a plate supported by means of screwed spindles and wheels from a flange cast on the cylindrical funnel revolves. The brush is formed in sections for convenience in handling and manufacture. In the periphery of the basin a number of openings are provided which are covered with wire or slotted steel plates. The rotation of the brush drives the slurry through these sieves into an annular chamber from which it passes to the mixing tank. The pieces of flint and other large particles are swept from the sieve by the rotary motion imparted to the slurry, and are discharged through an opening, provided with an adjustable slide, arranged near the bottom of the basin wall, and with a certain amount of slurry they are returned by means of a chute to the grinding-mill.

It is difficult to give figures which will convey an accurate idea of the capacity of the mill, for the thickness of the slurry has a considerable effect upon the output. With white chalk from the Thames and an average clay, the output per hour, when the slurry contains not less than 42 per cent. of water, of a mill having a diameter of 4 feet 6 inches will be a quantity representing 15 tons of raw material weighed in its naturally moist condition, *i.e.*, containing about 20 per cent. of water, the product having a fineness represented by a residue of 7 per cent. on the 180 by 180 and 1·4 per cent. on the 50 by 50 sieve. The coarse slurry with which these results were obtained gave a residue on the 180 sieve of 12·5 per cent. and 5 per cent. on the 50 by 50, while the returns gave a residue of about 15 per cent. on the 180 mesh sieve. The power consumed by the mill is extremely low, not exceeding 7 horse-power.

A comparison with the tube-mill is of considerable interest, and below the results of lengthened trials are given in abstract. The materials, chalk and clay, were of the character above described.

Per Cent. H_2O.	Wash-Mill Product, Residue per cent. on Sieves.							After passing Tube-Mill, Residue per cent.							After Clarke's Mill, Residue per cent.						
	180	120	100	76	50	30	20	180	120	100	76	50	30	20	180	120	100	76	50	30	20
42·3	11·39	...	...	...	...	...	...	6·37	...	...	...	0·64	...	...	...	...	...	...	...	...	...
40·7	11·84	...	...	...	...	...	...	...	...	...	...	...	...	...	7·64	...	...	...	1·34	...	...
40·2	14·0	10·61	7·21	6·6	5·0	3·3	2·0	9·4	5·33	3·12	2·21	1·28	0·41	0·21	...	...	...	...	...	...	...
40·0	15·65	10·60	8·40	6·86	5·5	3·4	2·24	7·41	4·41	3·17	2·24	1·29	0·46	0·20	...	...	...	...	...	...	...
44·6	15·52	12·18	10·80	8·64	6·92	5·47	...	...	...	...	...	...	...	...	9·67	6·07	4·41	2·91	1·71	...	...
43·4	14·8	12·4	...	6·65	5·31	4·02	...	...	...	...	...	...	...	...	8·91	4·35	...	2·61	1·31	0·44	...
41·0	19·84	15·4	11·29	9·99	8·16	...	...	...	...	...	...	...	...	...	12·93	7·92	...	4·14	2·66	...	...
42·5	12·60	8·61	7·89	4·41	3·15	2·02	...	...	...	...	...	...	...	...	9·89	...	...	...	0·74	...	...
42·8	10·41	...	...	...	...	...	...	...	...	...	...	...	...	...	6·86	...	...	...	1·77	...	...
41·0	8·60	...	...	...	...	...	...	...	...	...	...	...	...	...	5·76	...	...	...	0·77	...	...
42·2	7·40	...	...	...	...	...	...	...	...	...	...	...	...	...	6·80	...	...	...	0·81	...	...
43·0	8·62	...	...	...	...	...	...	...	...	...	...	...	...	...	6·69	...	...	...	0·95	...	...

In a number of works, mills of this type have been employed, and when suitably proportioned in relation to the output required, slurry of almost any degree of fineness can be produced. It is the writer's opinion, after considerable experience with the mill, that two of them, each 4 feet 6 inches in diameter, taking a slurry having a fineness represented by the following residues, 12 to 14 per cent. on 180, and 5 to 6 per cent. on 50, would give a product finer than would a tube-mill 3·9 feet in diameter and 16 feet long, at the rate of 15 tons of dry raw materials per hour.

The product from this machine is free from large particles of flint, such as would be present in the product from a tube-mill working upon flinty chalk, and the wear upon the accessory gear would therefore be less.

MIXERS

One of the most important parts of the plant of a cement works are the tanks for storing the slurry. They are usually called mixers, as the finished slurry is run into them and kept stirred; any slight variations in the composition of the wash being thus averaged. As a rule, the slurry from the mills has a fairly uniform composition if the wash-mill gang is properly controlled, and a rule is made that the tips of chalk and clay must be put-in in proper sequence. But the regularity is not sufficiently great to enable a good cement to be prepared from the slurry coming direct from the mills even with the utmost uniformity in charging the chalk and clay; moreover, it is not infrequently necessary to add a number of extra tips of chalk and clay to compensate for slight variations in the wetness of the raw materials, and occasionally it is found advisable, for certain reasons, to suddenly raise or lower the lime content of the mix. In some works, one such tank is employed into which the slurry is run from the mills, and from which it is drawn at the same time for feeding the kilns. But with only one tank, a great deal of time is employed in testing frequent samples of the slurry so as to avoid, as far as possible, any irregularities, more especially if the tank is low. It will readily be seen

that with the greatest care under such circumstances, it is impossible to prevent occasional dangerous variations, and therefore the convenience of having a number of tanks is apparent. The capacity of the storage is also of some

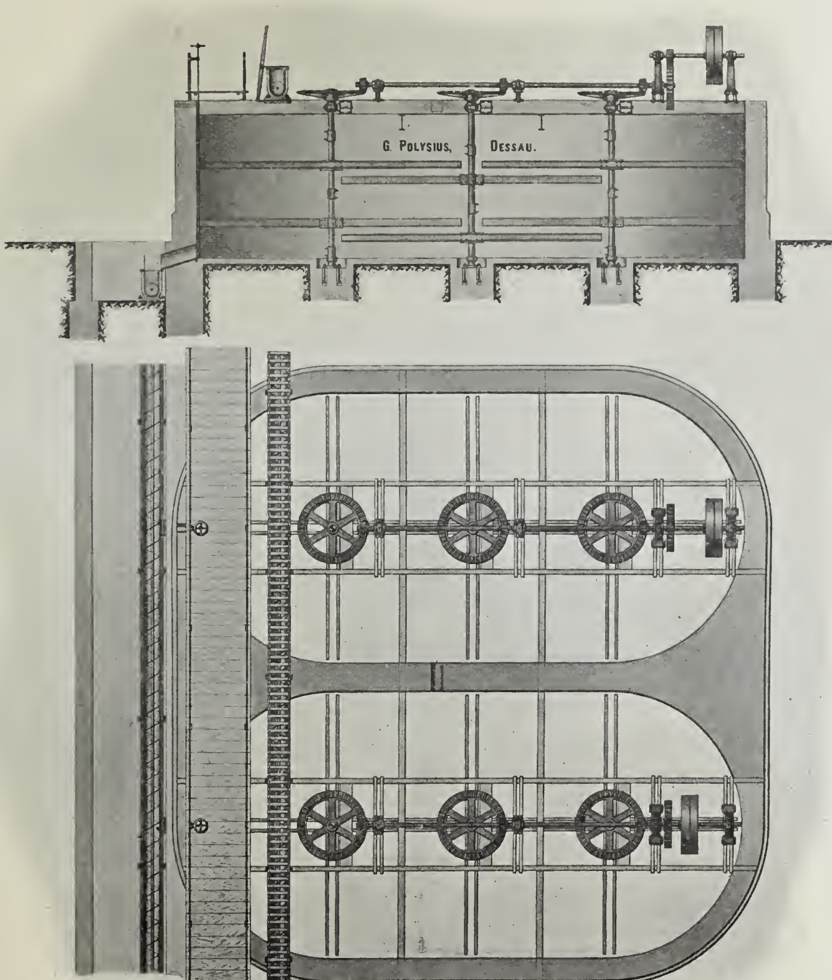


FIG. 13.—Mixer with Three Stirrers.

moment, as it is generally conceded that the duplication of staff rendered necessary by continuous night work is to be avoided whenever possible, to accomplish which, and to reduce week-end work to a minimum, it is therefore necessary

to instal a plant having a storage capacity to tide over these periods. The kilns, if they are rotaries, must be worked continuously, and the capacity of the mixers must therefore be sufficiently great to contain slurry to last at least thirty-six hours. The hourly output of the kilns being known, it is an easy matter to estimate the volumetric storage capacity. This will depend largely upon the percentage of water con-

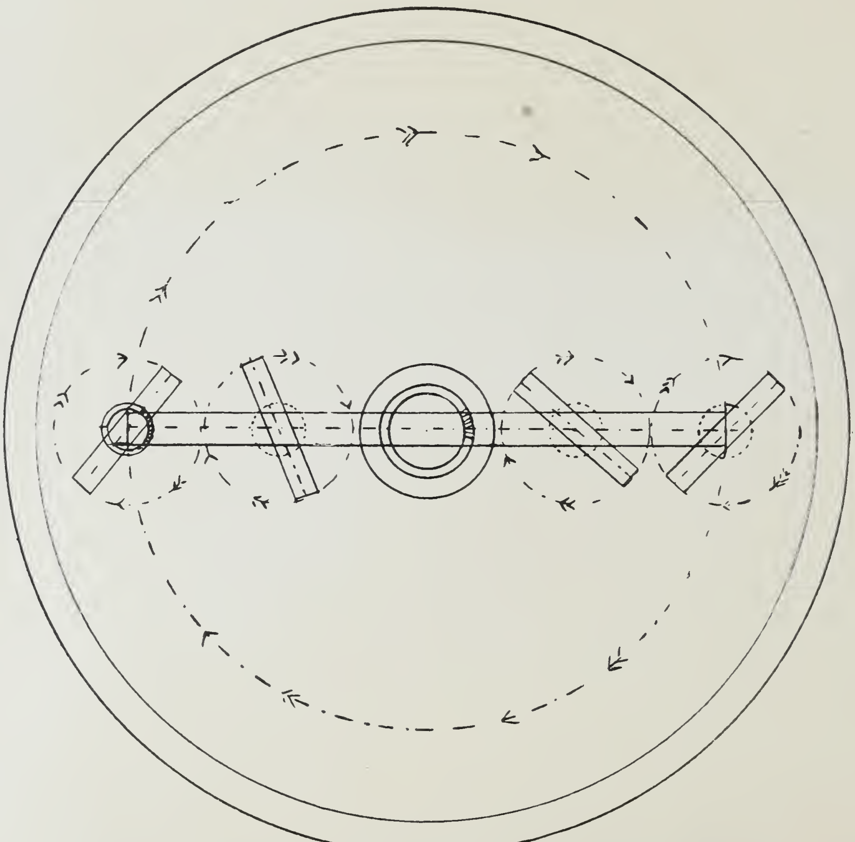


FIG. 14.—Diagram illustrating "Sun and Planet" type Mixer.

tained in the slurry. The proportion of water required to make a sufficiently fluid mass can be determined by an experiment, and from this result, in conjunction with the specific gravity and loss on ignition of a mixture of average composition, it can be accurately determined. For a guide the storage capacity can be taken as 57 cubic feet per ton of clinker; the slurry containing 40 per cent. of water, the

capacity being increased or decreased by 1·5 cubic feet per ton for each 1 per cent. above or below this figure.

The worst possible form of mixer is a circular tank in which a vertical shaft to which horizontal arms are secured is rotated at a slow speed, as such an arrangement is a most ineffective mixer. A simple and efficient arrangement is shown in plan and section in Fig. 13. The tank itself is constructed in brick or concrete, and from end to end extend two parallel joists which support the neck bearings for the vertical shafts, for which footstep bearings are also provided in the bottom of the tank. On the vertical shaft, channel bars are secured at suitable distances, and they are so arranged that the arms on the various shafts are at different levels. The stirring gear is operated from a lay shaft by means of bevel gearing. Some very large mixers of elaborate design have been constructed on the sun and planet system. Tanks with this type of stirring gear are circular in plan and at the centre they are provided with a pier to the top of which is secured a pivot and bevel wheel. A beam of suitable construction, supported on a pivot, is rotated by means of a bevel pinion engaging with the teeth of the rack secured to the pier. Four sets of stirrers are placed two on each side of the pivot and are rotated by bevel gearing from a shaft driven by the motor placed on a platform in the centre of beam. The operation of a mixer of this type is shown by the diagram in Fig. 14. While it is satisfactory with mixers of large dimensions, it will be found that the simpler type described earlier in this chapter is quite sufficient for those of average size.

ELEVATING AND CONVEYING SLURRY

For coarse slurry, and particularly when chips of flint are suspended in it, the slurry wheel and belt elevator are the most suitable machines, for the wear and tear on them is not increased by the coarse particles. The power required for either of the machines is small, being only that required to overcome the friction in the bearings, and to raise the slurry against gravity. If anything, the advantage with regard to power lies with the wheel, but this is more than outweighed

by the compactness of the elevator, notwithstanding the greater wear and tear with the latter machine. But the power consumed in elevating slurry is such a small fraction of the power consumed by the works—with an elevator it is approximately only three-quarters of a horse-power per ton of material raised per hour through 50 feet—that from the power-consuming point of view, the various machines do not have any material effect on the cost of production. However, the plant should be so arranged as to require the smallest possible number of machines both from considerations of capital outlay, repairs, and power consumption.

The old-fashioned chain pump has been employed to a considerable extent for raising viscous or muddy liquids. The wear and tear bill is, however, very heavy with slurries containing chips of flint, as they mostly do in this country. It consists of two pipes arranged vertically, above and between which a wheel is arranged in bearings. This wheel is provided with forks at certain distances around its periphery, or its rim is of semicircular section with or without webs at intervals extending across the channel. These forks or webs engage with the buckets or discs cast on the links of the chain at intervals corresponding with the pitch of the forks on the head-wheel. One of the pipes is provided with a bell which dips into the slurry, and on rotating the wheel the chain is drawn up this leg carrying with it the slurry, which is discharged into a chute at the top. The chain, after passing over the wheel, returns by way of the other pipe which acts merely as a guide and prevents any adhering slurry being dropped or splashed about the neighbourhood of the pump. The return pipe ends at the floor level. The power required for this pump is practically the same as that required by an elevator of similar capacity. But with high lifts there is less loss by spilling than is the case with elevators. A pump having pipes with a diameter of $2\frac{1}{2}$ inches will raise 90 cubic feet per hour, while one having pipes of $3\frac{1}{2}$ inches in diameter will raise double this amount. The capacity decreases with use owing to wear on the buckets and pipe.

In Fig. 15 a chain pump of the latest type is illustrated, and the details of construction clearly shown.

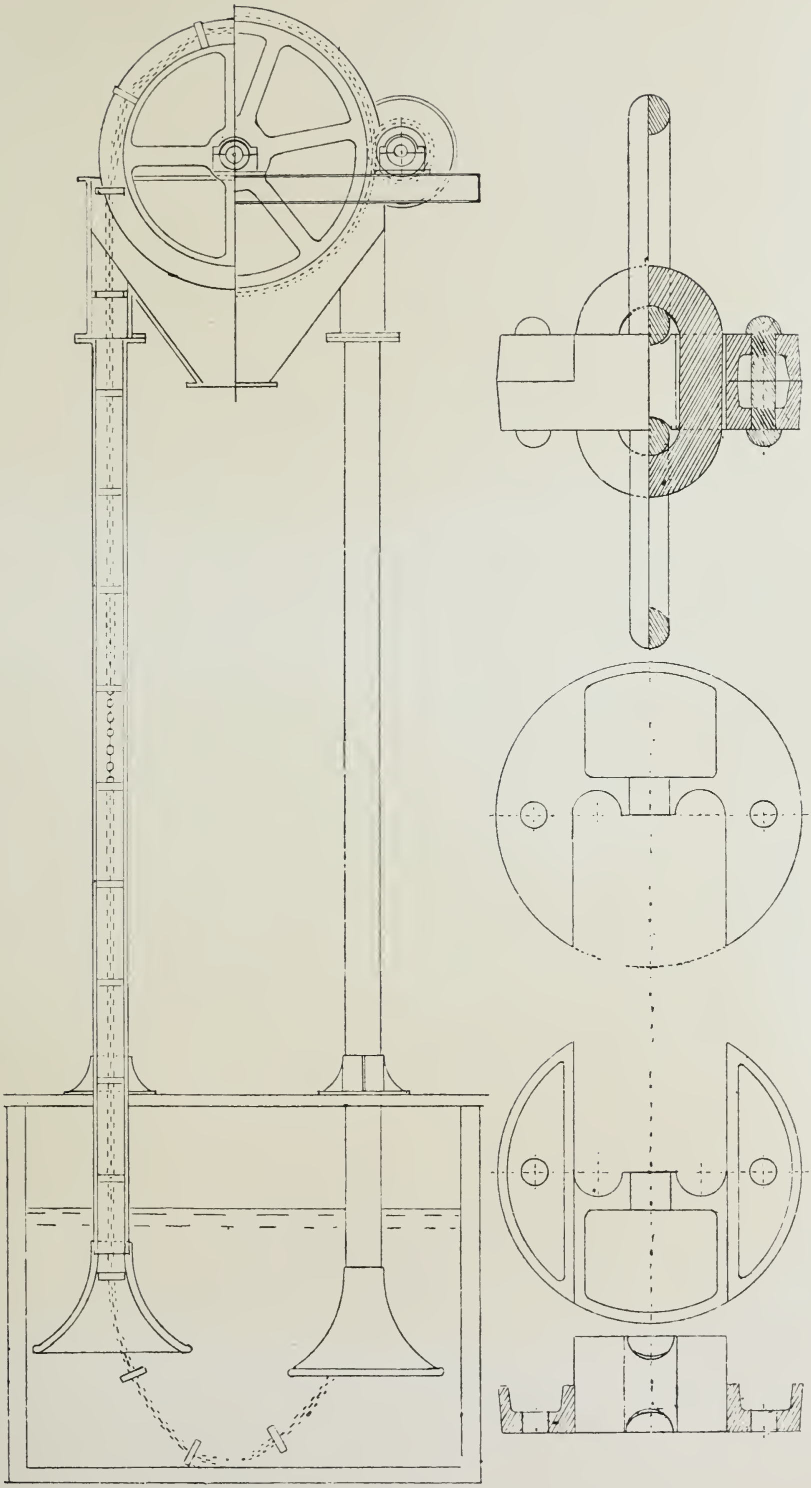


Fig. 15.—Chain Pump for elevating Slurry.

For fine slurry ram pumps are much employed, and they are most satisfactory when the slurry is free from chips of flint, but with flinty slurry considerable expense is caused by the scoring of the rams and of the valves. These pumps are of the outside packed type and are provided with either ball or rubber-faced flap valves. Each ram is provided with a spindle sliding in guides, and there are one, two, or three rams, the multiple rams giving a more continuous flow than pumps

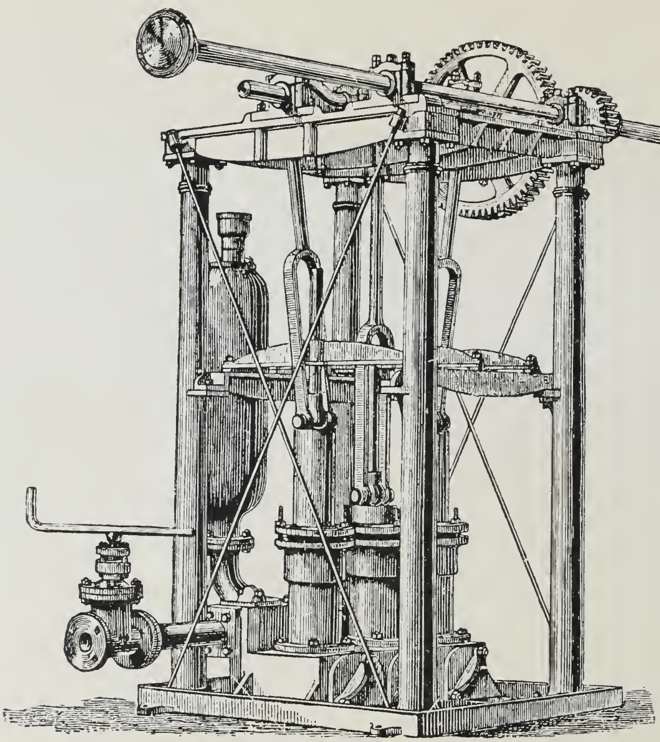


Fig. 16.—Three-Throw Ram Pump.

with only one, as they are so arranged that when one begins to draw the other has completed its suction stroke and the third has completed its discharge. A three-throw ram pump is illustrated in Fig. 16.

A ram pump of somewhat different design is illustrated in Fig. 17. In this case, as will be seen, there are four rams, for which guides are provided, in the yoke-piece above the cylinders. In place of the crankshaft employed in the pump illustrated previously, a shaft to which eccentrics

are keyed is employed. The valves are rendered easily accessible by removing the covers, the position of which is well shown in the illustration.

Channels or troughs are usually employed for conveying slurry, and these should be sufficiently narrow, and should have sufficient fall to cause the slurry to travel with as great velocity as possible. Otherwise they will need frequent

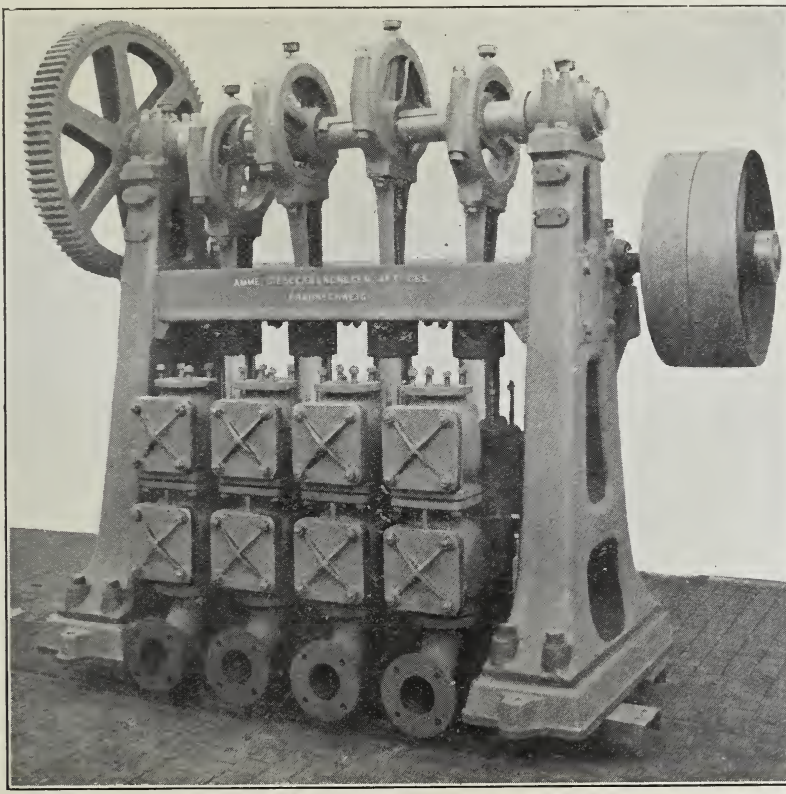


FIG. 17.—Four-Throw Ram Pump.

cleaning on account of the solid matter separating out. Worm conveyors are sometimes used for conveying thick slurry, especially on the Continent, but their employment only presents an advantage in a few exceptional cases. The amount of labour they save by rendering periodic cleaning of the troughs unnecessary is negligible when compared with their initial cost, wear and tear, and the power required for driving.

CHAPTER V

WET PROCESS—CONCLUSION

American practice in the wet preparation of raw materials differs considerably from the wet process as usually worked in Europe. In certain States, chalk of a very similar character to that employed in this country is found, and to a certain extent is used as raw material, but as a general rule the dry process is employed for preparing these softer rocks. Much has been said with regard to the relative advantages of the dry and the wet process, and very largely, those who hold one view or the other base their statement on other foundations than those which should be employed for the formation of a decision on this subject. During many years it was an article of faith in the cement trade in this country that grinding the raw materials with water was the only system whereby a thorough mixture could be obtained, and therefore cement made from materials treated in this manner was in every way superior to that prepared by the dry process. But the building up of an enormous industry in America, where the dry process is the most frequently used, it would be thought, was sufficient refutation of such opinions, more especially as for the time the cement produced gave greater strength than did the English product prepared by the wet system. Nevertheless, the opinion is still held by many, notwithstanding the fact that the raw materials usually treated by the wet process in this country have been treated by the dry process, and on a manufacturing scale in England, with the result that a cement equal in every way to the best prepared by the older system, and surpassing many so-called standard brands, has been produced. It is therefore impossible to maintain that the results are in any way inferior. As to whether these results are more easily or cheaply arrived at by the one process or the other, is a different question. It is also one which has

to be carefully thought out in every instance, and as an equally good cement can be produced by either system, the cheaper one is that which should be chosen. It is impossible to grind a hard crystalline limestone or a slate in a wash-mill, which, with softer material, is the cheapest grinding machine. At the same time, the harder and denser rocks do not have their strength lessened by the addition of water, because they absorb it to a much less extent. For which reason also, when quarried, they are drier, and therefore cost but little to prepare for grinding in dry-mills. A limestone suitable for building purposes may contain under unfavourable circumstances 6 per cent. of water when in a rough condition, consisting of large pieces mixed with a quantity of small stuff, while a chalk will frequently contain over 20 per cent., a clay about the same proportion, and a river mud over 30.

Taking, for an example, raw materials with 20 per cent. of water, and for another, 6 per cent., neither containing an appreciable amount of organic matter, the loss on burning will be about 33 per cent. of the weight of the dry raw materials. Then $1\frac{1}{2}$ tons of dry raw material will be required for each ton of clinker produced. For each ton of clinker produced, 4,200 lbs. of raw material would have to be delivered to the drier and 840 lbs. of water would have to be driven off, while in the other case 214 lbs. of water has to be expelled; in round numbers, the difference in quantity of water to be evaporated is 620 lbs. With an independently fired drier it has been found that 8 lbs. of water is evaporated per lb. of coal consumed. Accordingly, 77 lbs. more coal would be required by the softer than would be needed by the harder material in the production of a ton of clinker, that is, an increased coal consumption of nearly 3·5 per cent. As compared with the wet process, with slurries containing about 40 per cent. of water, the dry has the advantage of coal consumption in burning the raw materials of 5 per cent. of coal. It is therefore obvious that in the case of the soft raw material indicated above, as regards consumption of fuel, the advantage lies with the wet process. This advantage is, however, greater when it is remembered that actually 105 lbs. of coal are used on the soft material to evaporate the 840 lbs. of water contained in the quantity of

raw material required for the production of 1 ton of clinker, that is, a quantity of coal equal to 4·68 per cent. of the weight of the clinker. Consequently, merely looking at it from the point of view of the quantity of fuel required for burning and drying, there must be a difference of over 4·68 per cent. in coal consumption between the wet and the dry process for it to be profitable to dry them in independently fired driers. In certain cases, it has been found that with dry raw materials for a kiln of given length, a reduction of the quantity of coal required in burning of about 6 per cent. over that required for wet raw material is obtained, and this indicates a slight advantage on the other side, which, however, disappears when the relative cost of grinding is considered, and this would be fully 50 per cent. greater by the dry process.

When the waste gases are employed for drying raw materials, it must not be imagined that the operation is carried out free of additional expense for fuel in all cases. By lengthening the rotary kiln, it has been found that the output has been increased and the fuel consumption reduced. At the same time, however, the temperature of the gases leaving the kiln is also reduced, and when it is as low as 500 deg. Cent., unless the draught is impaired the gases cannot be employed for drying raw materials containing about 20 per cent. of moisture. And, if it is desired to raise this temperature, a greater consumption of fuel will result. The above considerations apply entirely to plants employing rotary kilns. When other forms of burning plant are to be used, the position is somewhat altered. The slurry produced in the wet process is in such cases dried on flats either separately fired or heated by the gases from the kilns, and in this operation the mass cracks, forming itself into irregular lumps which are loaded direct into the kiln. In this case, no additional amount of fuel for drying is required with Johnson or Batchelor kilns, but with the more modern continuous kilns no provision is made for drying the slurry by means of the waste gases, with the result that separately fired driers are required. The successful operation of a continuous kiln depends largely upon the regular size of the lumps or briquettes of raw material, and to obtain this, the raw

material is formed into bricks by mechanical means. With slurry this result is best arrived at by allowing the water to separate from the slurry and then passing the plastic material, containing about 25 per cent. of water, through a tempering trough, and converting it into bricks by means of a wire-cut brickmaking plant, the bricks thus formed being dried in a drier heated by live or exhaust steam, warm water, or hot air.

The wet and the dry systems, therefore, while equally satisfactory as regards the quality of the product, are not equally well suited to the treatment of the raw materials from the point of view of working cost. But as the cement industry has developed we find that they have been employed indifferently. In England, the materials, as a rule, have been soft, so the wet process has established its reputation here; in America, the harder materials are more largely employed, so that there the dry process is the more favoured.

The fresh-water marls of America are recent deposits of calcareous material occurring in marshes or at the bottoms of lakes. Their composition is not very different from a chalk, but they contain, as a rule, a higher percentage of silicious and aluminous material than does the white chalk of this country. It is found in the form of sand of varying fineness; 80 per cent. passing the 100-mesh sieve in certain cases, and in others giving a residue of 32 per cent. on the 20 by 20 sieve. Containing water in quantity up to 50 per cent., its drying is a costly operation, and being so soft and in such a fine state of division it is even more suited to treatment by the wet process than is chalk. Nevertheless, certain works employ the dry system of preparation although the greater number treat it by the wet. In the works which have adopted the latter process, the crude marl is run into tanks, and the clay or shale, often previously dried and ground in an edge-runner or disintegrator, mixed with a certain volume of wet marl, the two materials being incorporated in a pug-mill, after which the grinding is completed in wet tube-mills. In other cases the clay and marl are ground in wet pans, afterwards being finished in ball- and tube-mills.

With hard limestone, both materials are often dried and

pulverised in dry grinding-mills, and afterwards mixed with water in pug-mills. In Europe, the more usual system is to grind the clay with water and to run the thin clay slip into another wash-mill and to these add the hard limestone which has previously been crushed. The slurry obtained in this way contains the calcareous material as rather large particles and the use of a tube-mill or some other grinding-mill is necessary, the various types of sifting machines being entirely unsuited for the finishing process. Wet ball-mills or edge-runners are also employed in place of the limestone wash-mill as they can deal with harder material and the expense of drying which is necessitated by what is called in Germany the *halb-nass verfahren* (semi-wet process) in which the dry ground limestone is added from an automatic weighing machine to a measured volume of clay slip, the two being incorporated by means of mixing worms which are troughs in which two shafts, provided with paddles at intervals along their length, are rotated in opposing directions.

From the foregoing chapters it will be seen that a number of machines may be employed for the preparation of the raw materials by the wet process, and from the earlier portion of this chapter it will be appreciated that widely different systems have been evolved. Some fundamental principles have been considered which should be a guide to the choice of the most economical arrangements for the treatment of materials of any particular character, and the following schemes will serve to indicate the arrangement of the plant:—

I. Chalk and Clay or Materials of Similar Hardness.

Chalk — Water — Clay

Weigher — Weigher

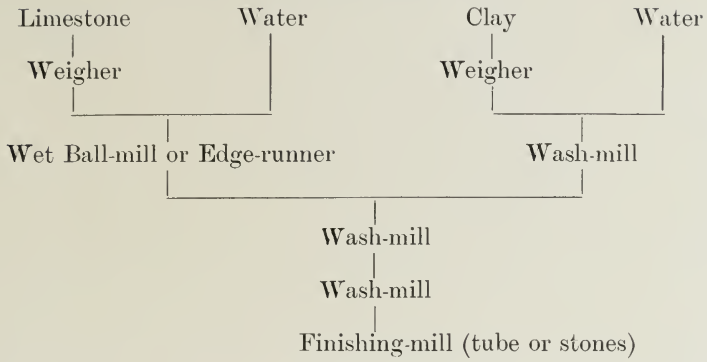
Wash-mill (coarse gratings)

Wash-mill (fine gratings)

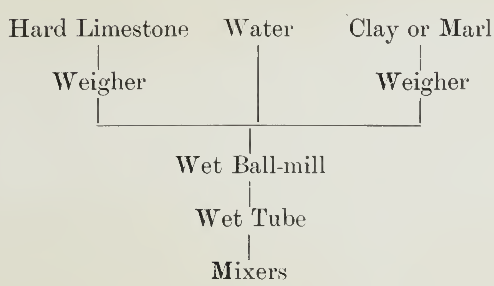
Finishing-mill, stones, tube, or sieve

Mixing Tanks

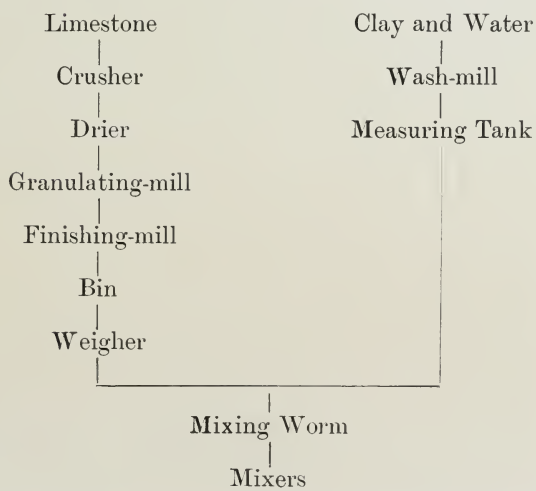
II. Hard Limestone and Clay.



III.



IV. Very Hard Limestone containing little Moisture and Clay.



BOOK II

DRY PROCESS

CHAPTER I

INTRODUCTION

In the dry process the raw material has usually to be dried by artificial means. The quantity of water that has to be expelled varies, and as it is of the utmost importance to reduce the amount of water to a low limit (not more than 2 per cent.) in order that clogging of the mill may be prevented, some form of drier has to be employed. The size of the pieces fed to the drier have a considerable effect upon its work; the larger pieces being more difficult to dry on account of the relatively small surface exposed by them. For this reason the rock is passed through a crusher which reduces it to a suitable size: about the size of a walnut. It then passes to the drier, which must be so dimensioned that it will reduce without difficulty the maximum amount of water contained in the raw material to the required limit. It then passes direct to the automatic weigher.

The crushed and dried rock are weighed and then pass through some form of mixer. The type most usually employed is a drum provided with a stationary filling head at one end, and a discharge at the other. The interior of the drum is provided with spiral blading or scoops so disposed that they thoroughly mix the material passing through the drum, as it rotates.

From this mixer it passes to a storage hopper which is provided to tide over any interruption in the working of

the drier or crusher. From these bins the material is taken to the dry grinding-mill where it is ground to a fine powder. The actual fineness to which the materials are reduced depends upon the composition of the raw materials. If they are totally dissimilar, that is, if one is a practically pure limestone and the other is a pure clay, then they have to be ground to a fineness represented by a residue of about 5 per cent. on the 180 sieve, while, if the two materials approach one another in composition, a much coarser meal will suffice for the production of a high-class cement.

The process of reduction may take place in one or two stages depending upon the class of machine adopted. Certain types of mill are well adapted for reducing lumpy material to meal in one operation, but many are totally incapable of such a performance and more are uneconomical when so employed.

Edge-runners are not infrequently employed for granulating, as the intermediate process of grinding is called in America, but as ordinarily constructed they are incapable of producing a sufficiently fine meal-like product such as is required in the cement industry for the raw meal, coal, or finished cement; while the ordinary type of tube-mill is equally inefficient as a machine for grinding material of the size of hazel-nuts. Centrifugal roll-mills, with which may be included horizontal ball-mills, are on the other hand universal mills reducing such coarse material to meal without difficulty. The other forms of centrifugal mill, such as the bar disintegrator and the swing-hammer pulveriser, like the vertical ball-mill, are purely granulating machines unless some form of sifter is combined with them.

Millstones and roller-mills hold a rather peculiar position among grinders in that they may be used for preparing widely differing classes of product. Millstones, for example, will grind very hard material to a degree of fineness such as is represented by a product leaving say 10 per cent. on the 50 sieve, or they can be adjusted to grind finer or coarser than this. For finer work, the wear upon the stones increases considerably; and for this reason they are, in such works where they were installed many years ago, now used simply

for preparing the feed for some more modern fine grinding machine. A very similar statement may be made with regard to roller mills which, unless used in conjunction with air-separators or some purely fine grinding-mill, cannot be employed for preparing finely ground products such as are now required in the manufacture of a high-grade Portland cement.

The materials, then, be they the dried raw stuffs, the coal required for burning, or the clinkered product, are reduced in two stages, with or without the use of independent separators or sieves, or the whole operation is carried out in one stage with certain types of mill, in which case a separator of some kind is always employed. In the descriptions of the various modern types of grinding machines which follow, it will be seen that there are certain types which are really compounded machines, and the fact of their employment though apparently opposing the above statements does not actually do so.

In theory the greatest efficiency with reducing machinery is obtained when the size of the particles constituting the feed is uniform, and when the fine particles produced in the grinding operation are abstracted from the mill as soon as formed. In practice, however, this ideal can only be approximated, some fine material suffering a further reduction and some coarser particles passing through but little reduced in size, as the fine stuff forms a hiding place for such nibs. These nibs or chips are a source of no inconvenience in the finished cement if it is well burned and of proper composition and the "overfine" particles are of great value, but in the preparation of the raw material the reverse is the case especially when one of them is a practically pure limestone. From this point of view the best type of mill for reducing the raw materials is one in which the fine particles are removed as soon as they are formed, but the cost of repairs is a matter of considerable moment, and it often happens that such mills as will operate well from one point of view are expensive from the other. The expenditure of a certain amount in additional power is usually of less moment than constantly recurring expense in repairs, so that the most

simply constructed machines are often chosen in preference to more complicated and, we had nearly said, therefore, those which are more delicate and costly on account of upkeep.

The raw meal as it comes from the mill is stored in silos, each cell being capable of holding sufficient material for a six hours' run of the kilns. The meal passing to the silos must be tested for fineness at regular intervals, and its composition must be determined by partial analysis. As a rule, the determination of its content of calcium carbonate suffices, this determination being made with a fair degree of accuracy by titration with standard acid or by the calcimeter.

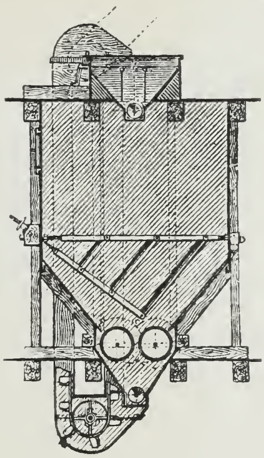


Fig. 18.—Mixing Silo.

To correct any irregularities in the composition of the raw meal admixtures of an additional proportion of the more calcareous or argillaceous material are made, and to render the mixture uniform, the contents of the cell are mixed. This operation is performed by abstracting the material from the bottom of the cell and returning it at the top, or some special mixing device may be employed.

One form of mixer is shown in Fig. 18. It consists of a hopper-bottomed case into which the material is fed and distributed by a spiral conveyor. Falling downward, it is distributed by means of two rollers along the trough of another spiral conveyor, situated at the bottom of the cell, and being conveyed to the boot of an elevator, it is returned to the upper conveyor. Other forms of mixing machines consist of troughs in which one or more sets of propeller-like blades revolve at high speed.

When the rotary kiln is employed, the raw meal passes directly to the small storage hopper situated above the higher end of the kiln. With stationary kilns, whether of the intermittent or continuous class of kiln, the material has to be formed into briquettes.

CHAPTER II

CRUSHERS

With raw material possessing so great a degree of hardness as those most frequently employed in America, the wet process, as usually worked, is inapplicable ; and for this reason the dry method of preparation came into adoption to a very large extent. The dry process had been previously worked to some extent in England, in the Rugby district, where the Lias limestones are employed in the manufacture of Portland cement, and at a later date it was adopted for the preparation of other raw materials found in this country. But the development of the dry process took place on the Continent and in America, the methods adopted in those places being introduced into this country where at this day but a small proportion of our total output is produced by such means.

The raw materials, as treated by this process, when brought to the mill are broken into small pieces which, after drying, are ground to the requisite degree of fineness. The first operation of roughly breaking up the stone is carried out in one or other of two types of machine depending upon the physical character of the material. If it is hard and contains but a low percentage of moisture, it is cracked between two surfaces which alternately approach and recede from one another. On the other hand, those which are soft are more easily reduced by passing them between hedgehog rolls. The former class of machine are usually called crushers, crackers, or breakers. They may be divided into two classes, those in which one of the jaws reciprocates, the other being stationary, and those in which a cone gyrates within a ring. This machine is illustrated in Fig. 19.

It consists of a hopper-shaped casting at the top, below which is an inverted cone supported on a casting which also

serves as a support for the driving mechanism. To the central hollow shaft another cone is secured which is gyrated by the rotation of the bevel wheel cast with an eccentric boss. This boss projects into the central shaft, which is provided with a white metal bush. The material is fed into the hopper and settles between the surfaces of the cones, and on rotating the countershaft by means of the pulley—which

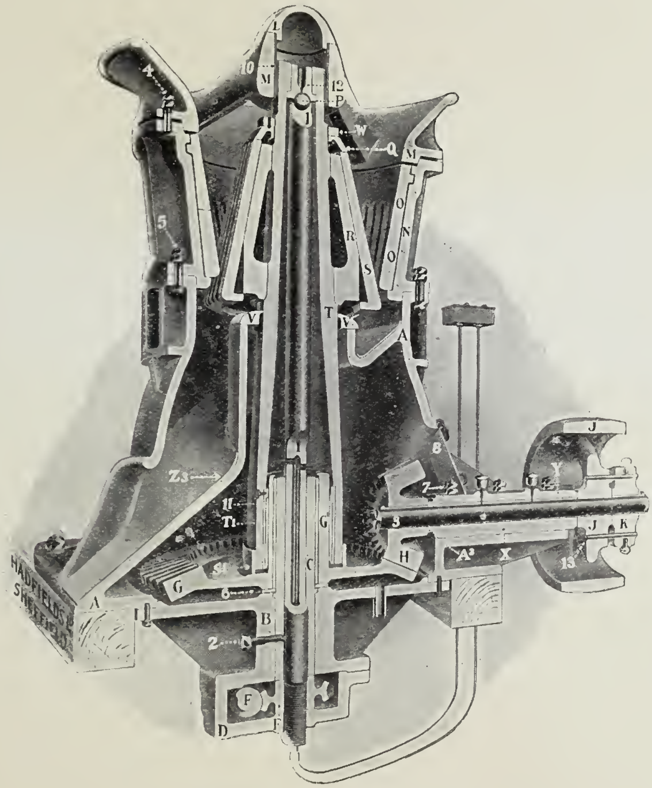


Fig. 19.—Gyratory Crusher.

drives through breaking pins to prevent injury to the machine, consequent upon a piece of iron getting between the jaws, or similar accidents—it is crushed by the inner cone approaching the outer one, and that which is broken sufficiently fine drops on to the sloping diaphragm as the cone continues its gyration, upon which the material settles in the hopper ready for another grip. This process progresses con-

tinuously round the whole path of the inner cone in the manner shown by the diagram in Fig. 20.

The size of the product is varied by raising or lowering the inner cone by means of a worm and worm wheel situated at the bottom of the machine.

In the particular design of gyratory crusher shown, there are numerous unique features, among which are the facing of all wearing parts with manganese steel, the taking up of the thrust of the moving cone by means of an inner vertical spindle and a bronze ball instead of by a steel step at the lower end.

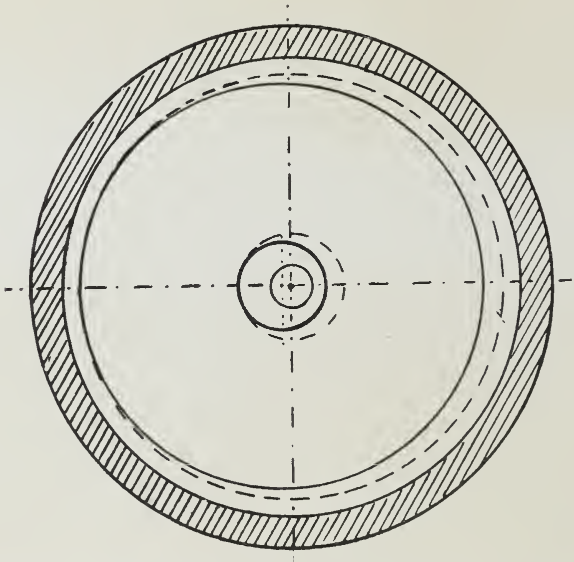


FIG. 20.—Diagram illustrating Action of Gyratory Crusher.

The power required for crushing large lumps of limestone to pass a $2\frac{1}{2}$-inch ring varies from 1 horse-power per ton per hour in the smaller sized machines dealing with 20 tons per hour, to less than 0·5 horse-power per ton per hour in the largest size, that is, one capable of dealing with 200 tons per hour.

The older type of machine employed for preliminary reduction of hard materials is the Blake jaw crusher. In the original design of this machine one jaw is formed by facing one of the short sides of a box-shaped casting with a chilled iron plate, and the other jaw is suspended by a spindle

supported by horns from the main casting. At a certain distance behind this spindle, the driving shaft, provided with an eccentric, is journalled, and by means of a pitman and toggles the moving jaw is driven towards the fixed, on rotating the eccentric shaft. The size of the product from this machine is regulated by raising or lowering the wedge at the rear of the machine. When working on hard limestone and crushing pieces of a size which just permits of their entering

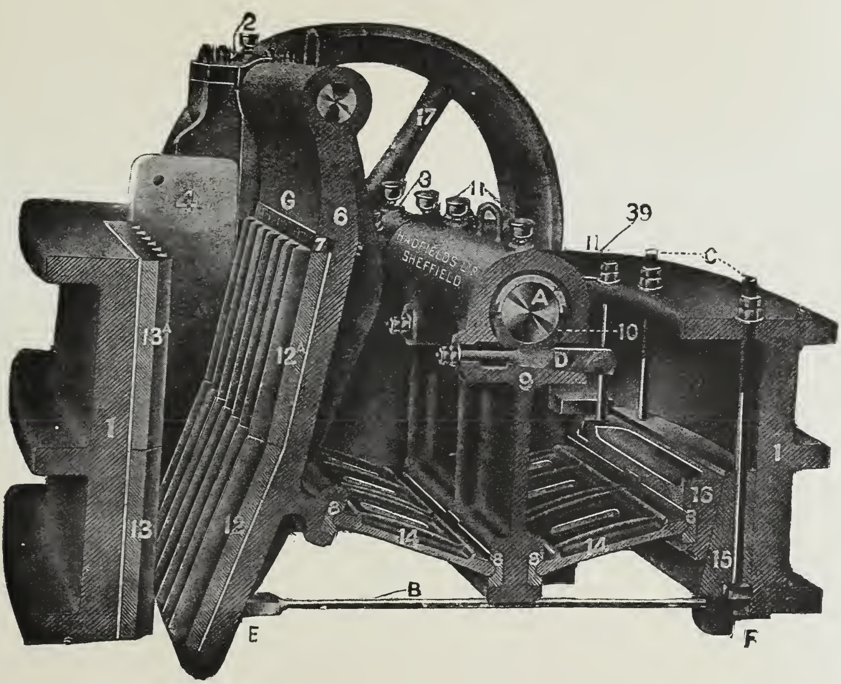


Fig. 21.—Jaw Crusher, with Cast-Steel Frame and Manganese Steel Jaws.

the receiving opening, to material which will pass a $2\frac{1}{2}$-inch ring, the power required is as near as possible 2 horse-power per ton.

In a later design, usually known as the Blake-Marsden "Frictionless Lever" crusher, the reciprocating action is produced by means of a rocking lever and pitman.

The frame of the foregoing jaw crushers is usually made of cast iron but cast steel has been employed instead, as by this means the weight of the machine can be reduced by one-

half, while at the same time its strength is over three times that of the more common machine with a cast-iron frame.

Another type of jaw crusher is illustrated in Fig. 22. The frame of this machine is built up of mild steel plates. One jaw is fixed and the other is oscillated by means of a lever bearing against a cam, the lever being provided with a roller which is kept in contact with the cam by means of a spring. The operation of this machine can be best understood from the figure. The speed at which the eccentric shaft of the Blake crusher is driven is 250 revolutions per minute, while in this machine it is only 150, but at the same time the number of oscillations of the jaw per minute is 300

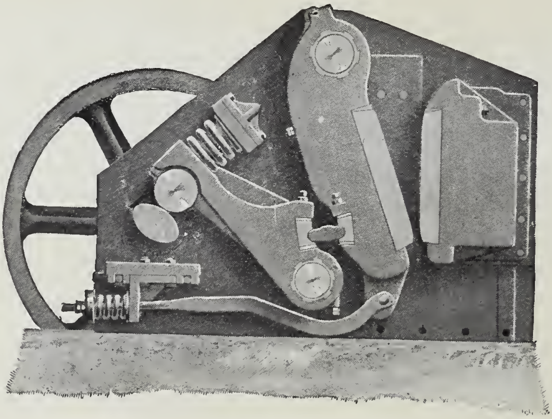


Fig. 22.—Steel Plate Crusher.

in the latter case, as against 250 in the former, and at the same time the output is greater, and the power required is less with the cam and roll machines as compared with the other type; the size of receiving opening being approximately the same, and the feeds and products being similar in both cases.

The machines just described are especially adapted for coarse crushing, that is the reduction of the material so as to pass a ring no smaller than the 1 inch. For feeding ball-mills, the feed may be much larger without notably influencing the output of the machine or increasing the power consumption, but certain classes of mill, such as the horizontal ball-mills, pendulum, roller mills, and millstones, work considerably

better when the material fed into them has been previously reduced to a much greater degree. For this reason occasionally other types of crushers are employed differing somewhat in design from those previously described, but nevertheless being closely related.

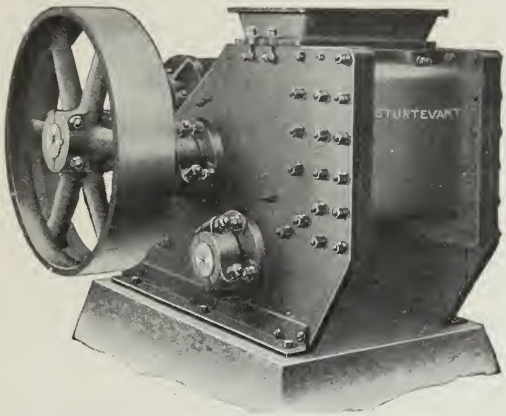


FIG. 23.—Roll Jaw Crusher.

In Fig. 23 such a machine is illustrated, the action of the jaws being of a rolling as well as a nipping type. The fixed jaw is secured in the frame of the machine and the oscillating jaw is hung from a link supported at its upper end by a spindle turning in bearings above and a little behind the moving jaw. A lever backed by toggles projects from the rear of the rolling jaw and is operated by means of a cam shaft upon which it bears through a large roller, a spring serving to keep the roller and cam in contact. This machine, with receiving opening 24 inches by 8 inches, will crush large hard lumps, giving a product passing a $\frac{1}{2}$-inch ring and containing a large quantity of fine stuff, at the rate of 8 tons per hour, for which duty it will consume 24 horse-power.

FIG. 24.—Rotary Crusher.

For the reduction of the softer raw material a type of machine has been employed which is very similar in design

to the common coffee-mill. The product turned out by them is of a sandy nature, practically all the particles being less than $\frac{1}{8}$ inch in diameter. This class of machine has been extensively used for a variety of purposes in the mineral and chemical industries; it has, however, been adapted in the cement trade to a very limited extent and then chiefly for crushing coal. For the sake of completeness an illustration of such a machine is given in Fig. 24. It may here be mentioned that its cone merely revolves and does not gyrate

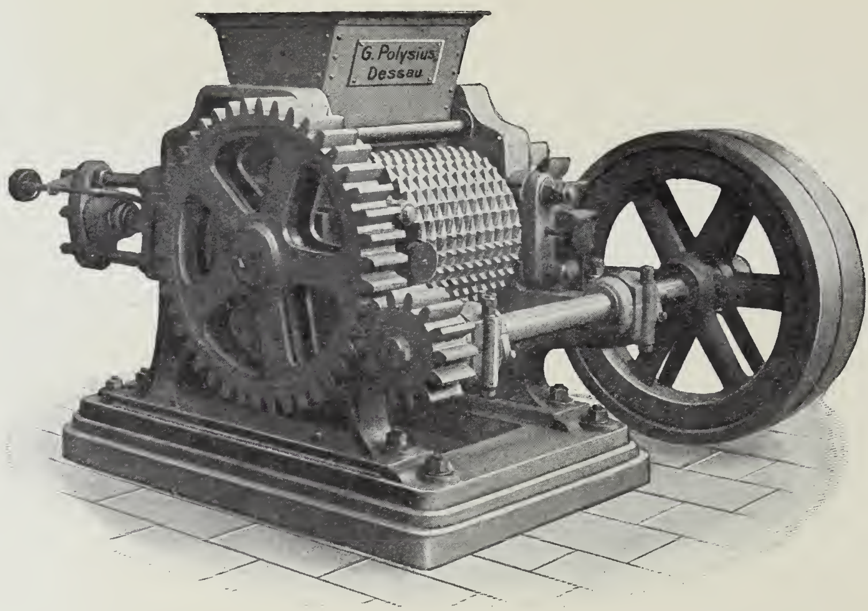


Fig. 25.—Roller-Mill with Toothed Rolls.

as does that in the crusher described in the earlier portion of this chapter.

The preliminary reduction of the soft raw materials, such as chalk, Cambridge marl, and clay, is best carried out with hedgehog rolls. In this machine two rollers are placed opposite one another. One roller is driven by a belt or spur gear, and from it the other roll is driven by spur wheels with deep teeth. The roll, which receives its motion by belt from the line shaft, is journalled in fixed bearings, while the other roller is supported in sliding bearings which allow of the

distance between the rolls being regulated by means of screws passing through buffer springs. These springs allow the roller a certain amount of lateral motion, thus preventing the belt being thrown off or teeth being broken out by the passage of hard pieces between the rolls.

The shells for the rollers are made in a great variety of forms, and the material from which they are formed is either iron cast in chills, steel, or manganese steel.

The dimensions of the teeth are regulated by the character of the material to be dealt with, and the size of the product which it is desired to obtain.

The shells are frequently cast in one piece, but equally common are segmental shells in the form of rings or of segments equal in width to the face of the roll but only covering one-sixth of its circumference.

CHAPTER III

DRIERS

THE raw material as it comes from the crusher must be dried previous to being further reduced in size, as the tendency of most material is to clog the various forms of mill employed. Indeed for this reason the softer raw materials, on account of the quantity of moisture they usually contain in temperate climates, must be dried before they can be crushed in such a machine as the rotary crusher. The practice in respect of proportioning the materials varies in different works, some of which weigh their raw materials and tip them into a common crusher from which they pass to the drier, while others crush and dry the two materials separately, afterwards feeding them from storage bins to automatic weighers, by which means they are correctly proportioned; the mixture then passing to the grinding-mills. The latter system is to be recommended, as, being dry, the materials have a more constant composition, rendering the alteration of the weights on the machine less frequent than would be the case if the materials were weighed as delivered to the mill, which alterations would be particularly frequent when two materials of widely differing porosities are employed. For this reason driers are treated of at this stage, weighing machines being dealt with at a later.

The moisture contained in the raw material varies between wide limits, materials containing over 30 per cent. of hygroscopic water being not infrequently treated by the dry process; the content of the materials usually prepared by this system, however, does not commonly exceed 10 per cent. and a figure of between 3 to 8 per cent. may be taken as generally representing the proportion present. The driers in use are continuous in action and in the most recent plants take the form of rotating cylinders. Previously very rudimentary systems

were employed which were discontinuous in operation and therefore are inferior to the newer systems on account of the labour costs in operating them. Before the general adoption of the rotating drum for burning, the continuous driers were built on the lines of a vertical continuous kiln, and in several cases old kilns have been modified so that they could be employed as driers. A type of vertical drier is shown in Fig. 26. The material is fed into the top of the shaft by means of an elevator and falling round the inner cone meets with a current of hot gases consisting of a mixture of air and the products of combustion of the fuel on the grate. The moisture is

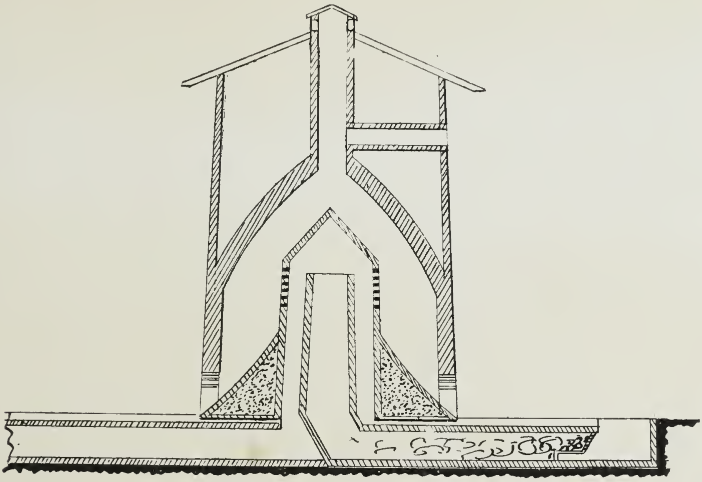


Fig. 26.—Shaft Drier.

expelled from the stone fed into the drier which descends, as the dry material is drawn from the eyes situated at the bottom of the shaft. This type of drying tower is either worked with natural, forced, or induced draught, and the arrangement of the canals is varied to suit these circumstances: for example, the supply of additional air is often delivered by a duct situated above the furnace.

By the diagram, Fig. 27, another drier which met with some adoption is illustrated, and from the sketch the mode of operation can be easily grasped. On to the top cone the material is fed by any suitable device; it descends and is caught by the hopper-shaped trough, continuing to travel

in this zigzag fashion until it reaches the bottom of the tower. A furnace is arranged below, the hot gases from which cause the expulsion of the hygroscopic moisture.

A tower drier of peculiar design is in use at the Edison Works at New Village. This drier is a tower of square horizontal section and it is provided with three groups of inclined baffle plates. The topmost group are oscillated at

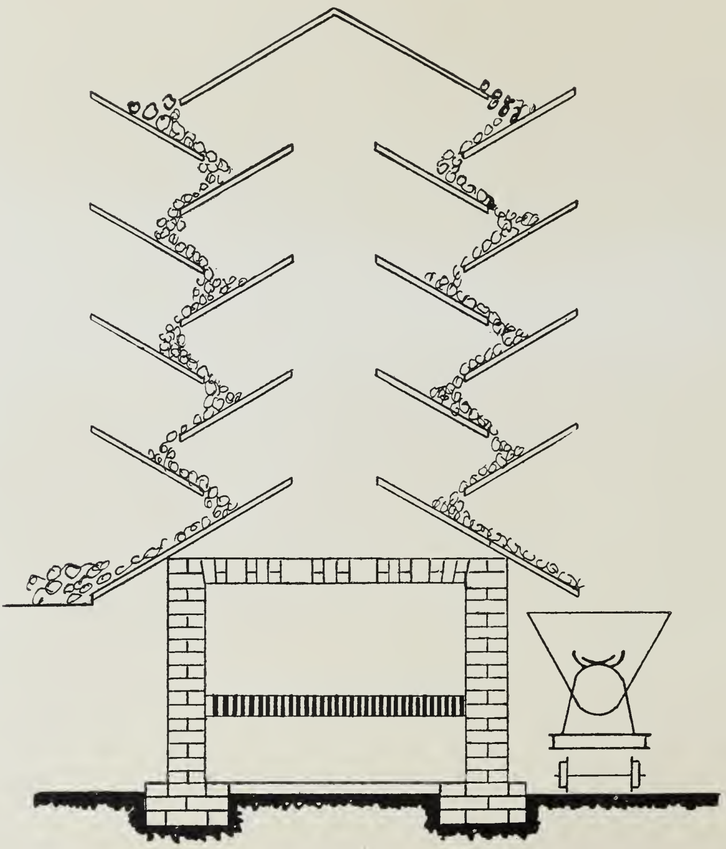


FIG. 27.—Diagram illustrating action of an old form of Tower Drier.

intervals to prevent the moist raw materials settling into a compact mass, while the two lower groups are stationary. The arrangement of the baffles is such that it takes twenty-six seconds for the material to descend the tower, and when it arrives at the bottom it contains less than 1 per cent. of moisture. The heat from the drying operation is obtained from a furnace arranged by the side of the tower, the furnace

gases being introduced at three different levels. The tower is capable of treating 3,000 tons per day and is 40 feet in height, its horizontal section being a square of 8 feet side. It is stated that the efficiency of this drier is good, and that the gases leave it at a temperature of little above 100 deg. Cent.

Rotary driers are now almost universally adopted, as they are compact, continuous in action, and although taking some power for driving, the amount is inconsiderable. In efficiency the several types differ considerably, as can be readily understood from a brief consideration of their methods of operation. For example, in some driers the hot gases travel in the same direction as the material which is being dried, while in others they travel in opposed directions. In the former case, the dried material leaves the drum at a lower temperature than in the latter, and at the same time the material in its wettest condition comes in contact with the gases when at their hottest, while in the other case the position is reversed. Again, the gases may be made to pass both round, as well as through, the drier or they may be merely taken through and thence to the chimney. The heat necessary for the purpose may be obtained from independently fired furnaces, or the flue gases from the kilns or hot air from the coolers may be employed.

The simplest form of rotary drier is a slightly inclined tube built up from boiler plate, the inside of which is provided with channel irons extending its whole length and situated at equal distances round the drum. The drier is rotated by means of spur gearing and is supported on two tyres which bear on rollers. The material is fed in at one end and the channel bars lift it, as the drum rotates, raising it until they are inclined sufficiently for the material to fall from them in the form of a cascade. In this way the stuff is repeatedly turned over and brought into intimate contact with the current of hot gases.

Another form of drier which has been extensively adopted is the Ruggles-Coles. In this design the drier is formed of two concentric cylinders, the inner being secured to the outer at its middle by means of cast-iron brackets, additional support being given by a number of arms suitably placed and

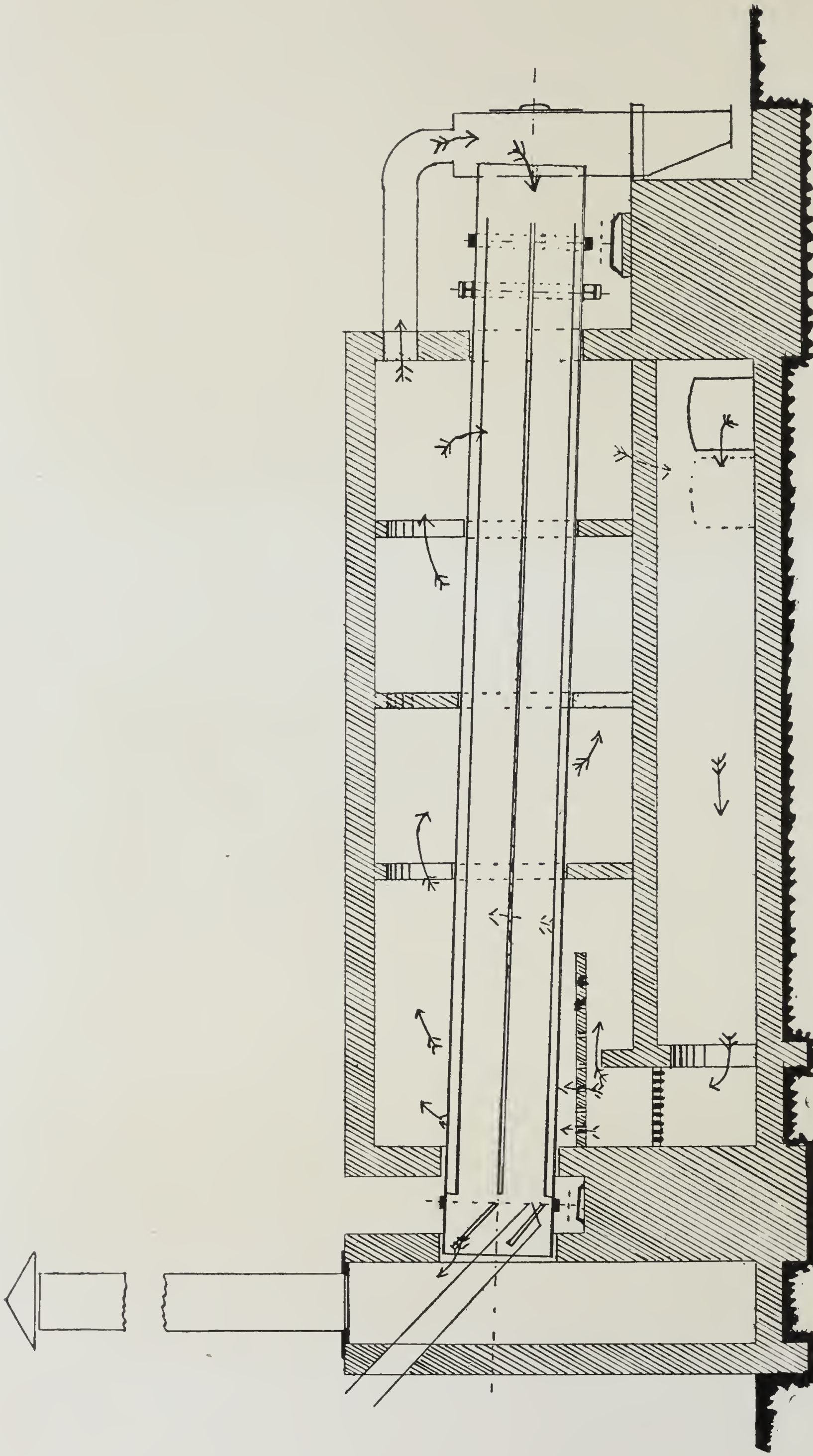


Fig. 28.—An arrangement of Rotary Drier with Furnace.

so arranged as to permit of alterations in length due to temperature. The inner side of the large drum and the exterior of the smaller cylinder are provided with scoops which act in a similar manner to the channel irons in the type of drier which was previously described. The drying drum, supported in an inclined position and bearing by means of tyres upon rollers, is rotated by means of a spur gear. At the upper end a furnace is provided, and the hot gases are drawn through the inner drum and then back through the space between it and the outer drum by means of a fan, while the material fed in at the upper end between the two drums passes downward and is discharged at the lower end.

The evaporation with this type of drier working on wet granulated slag is frequently as high as 8·5 lbs. of water per lb. of coal consumed; the slag contains 40 per cent. of water

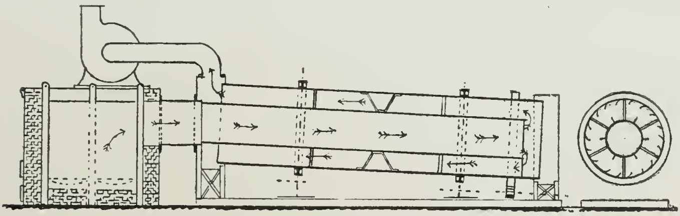


Fig. 29.—The Ruggles-Coles Drier.

as fed to the drier, and the output of dried material is about 3 tons per hour. The application of the hot gases is somewhat peculiar in the type of drier which has just been described, for the wet material comes into contact with the hottest part of the inner shell as it enters the drier, and at the same time with the gases at their coolest just previous to their being drawn into the fan casing. In the driers constructed according to the system of Dr Moeller and Professor Pfeiffer, the gases, when at their hottest, come into contact with the freshly introduced raw material which travels in the same direction as the gases; the dry material, therefore, is discharged at a lower temperature than when the gases pass in the reverse direction, with a corresponding increase in heat economy. The furnace is arranged at the feed end of the drying drum, and a fan blows a part of the furnace gases,

which have already passed through the drum, in at a certain distance above the grate; the mixture then passes through the drier to its lower end, and discharging, a part is led back by a flue arranged beneath the drum which also acts as an expansion chamber or dust collector, and the surplus gases are discharged into the air. The drum is divided into a number of parallel cells, which arrangement causes the material and the hot gases to be brought into intimate contact. The Cummer drier consists of a furnace, drying drum, and dust chamber. The furnace is provided with an automatic stoker of either the rocking step-grate or of the push-bar horizontal grate type. Above the grate a large surface of fire-bricks is presented to the flame, with the result that almost perfect combustion is obtained, while at the same time the extremely hot gases do not come into direct contact with the drier drum, causing calcination of the material. By way of a number of trumpet-shaped elbows the hot gases pass into the drum near the point where the wet material is introduced, and travelling upward they pass by way of a flue and bent pipe to the dust-collecting chamber above. From this chamber by means of two stacks they pass to the atmosphere. The greater portion of the dust is settled in the dust chamber by the reduction in velocity of the gases passing through it, while the remainder can be precipitated by the employment of a water spray. The dry dust is collected by a spiral conveyor and delivered to the worm conveying the dried raw material from the drum. The more complicated forms of driers are but rarely employed with rotary kiln plants, the plain cylindrical drum heated by hot air or the flue gases being more generally adopted. From the plans of actual works given elsewhere, the arrangement of the driers with relation to the kilns can be seen. It is quite general practice to employ hot air from the clinker coolers for drying the coal while the flue gases are employed for drying the raw materials. In several works the flue gases are employed for coal drying, all the hot air from the coolers being employed for the combustion of the coal in the kilns. The increase in length of the rotary kiln results in increased fuel economy in burning the raw materials, and at the same time the heat

contained in the flue gases is reduced. With the lengthening of the kiln the point is approached when the gases can be no longer employed for drying, and it is suggested that with a kiln 250 feet in length this point would be reached. It is certain that the reduction of the flue gas temperature below a certain figure (*circa* 180 deg. Cent.) would necessitate the use of mechanical draught.

CHAPTER IV

MILLSTONES, EDGE-RUNNERS, DISINTEGRATORS, &c.

MILLSTONES were at one time used very extensively for finishing cement, and for dry grinding generally, but they have been now almost entirely superseded by other forms of mill. And if employed at all the stones are set further apart and the mill is used for preparing the material for subsequent reduction in more modern types of grinding machinery. The horizontal form of mill in which stones are employed has already been described in some detail in the chapter dealing with wet millstones. The speed at which the stones are rotated is, however, doubled when the mills are employed for dry grinding, that is, the runner is driven at a peripheral speed of about 1,800 feet per minute.

LEADING PARTICULARS OF MILLSTONES (DRY).

Diameter of stones - - - -	3 ft. 3 in.	4 ft.	5 ft.
Revolutions of stones per minute -	180	140	120
Power—upper runner - - -	12	20	25
under runner - - -	8	15	20
Output per cent. on 76 by 76 sieve—			
Upper runner { clinker - -	6 cwt.	10 cwt.	16 cwt.
Upper runner { limestone -	8 cwt.	12 cwt.	1 ton.
Under runner limestone - -	12 cwt.	1 ton.	1 ton 10 cwt.

The millstone with emery grinding surfaces is also used for dry grinding. In design it is similar to the mill illustrated in the chapter dealing with wet stones. The output of a 42-inch mill of this type is from 1 to 3 tons per hour, depending upon the hardness of the material ground, and the fineness to which it is reduced. The speed at which the

runner is driven is 350 revolutions per minute and the power consumed is 18 horse-power.

A form of mill in which the material is ground between a pair of stones is illustrated in Fig. 31. It will be seen from this section that the stones are placed vertically, one being rigidly held in the casing and the other secured to a

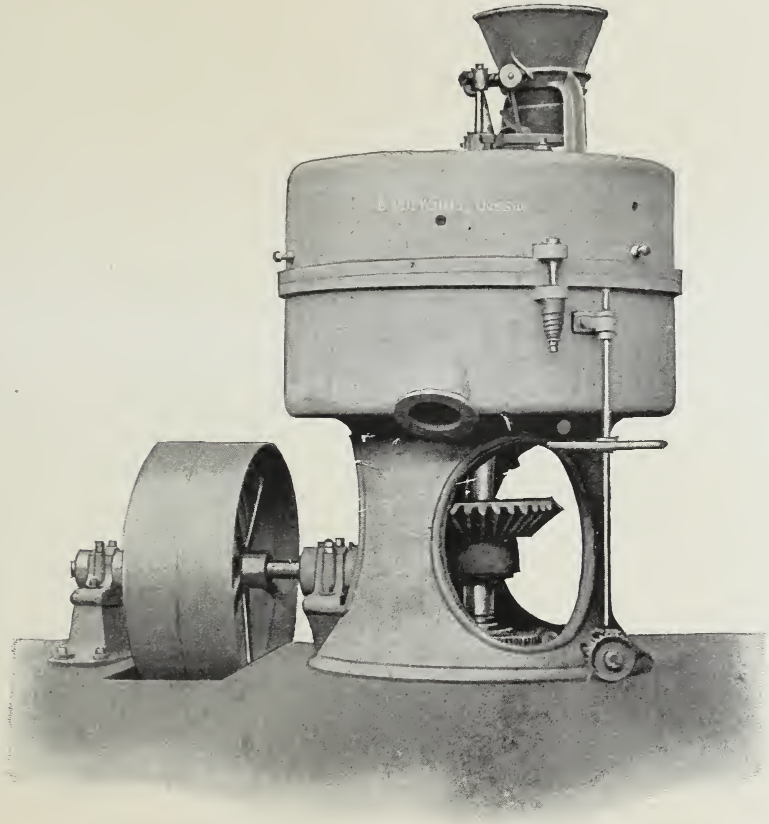


Fig. 30.—Under Runner Millstone.

shaft. The material is fed into the centre of the mill by means of the vertical channel shown and is carried between the stones by a screw sleeve secured to the driving shaft. The rotation of the stone drives the material toward the skirt of the stone, after passing which it is discharged by means of an opening in the casing situated slightly above the centre line of the mill. The stones are built with

burr stone centres and furrows, the skirt being formed of lumps of rock emery, set with the grain at right angles to the face of the stone, the whole being run in with metal. The runner is secured to a cast-iron disc, which is provided with channels in which balance weights are secured. The runner being rotated at the high peripheral speed of 5,000 feet per minute has to be carefully balanced, which operation is performed by regulating the distance of these weights from the centre. The fineness of the product is regulated by adjusting the distance between the stones by means of the hand-wheel situated at the end of the shaft where the ball thrust bearing is also situated. These mills are not well adapted to the reduction of very hard material, the

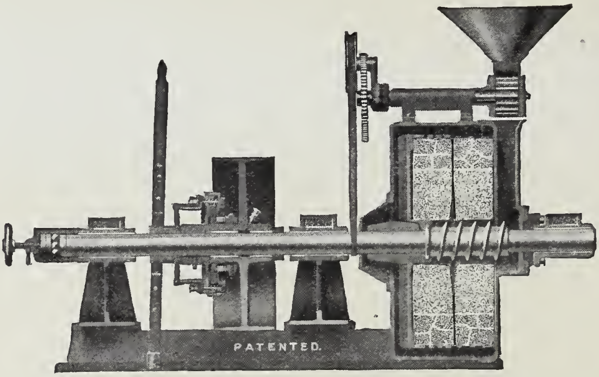


Fig. 31.—Sturtevant Vertical Emery Millstone.

horizontal form being more suited to this purpose. On moderately hard material the output is large, having regard to the power consumed.

The edge-runner mill has been adopted in a number of works for dry grinding; at the present time its application is restricted to the reduction of the raw materials and it is used for preparing the material for subsequent reduction in other mills. The machine, as applied in cement works, is required to produce in some instances a product which will pass a $\frac{1}{4}$-inch ring while in others it is used for the reduction of material to pass a 30-mesh sieve. Its precise position among grinding machines has provided a field for discussion. In the milling of gold ores it has been ex-

tensively adopted in conjunction with a Spitzkasten, and by some engineers it has been held to be inferior as a sliming mill to the tube-mill, while superior as a producer of grit, while others have held that it is equally well suited for either operation. So far as the cement industry is concerned, as a fine grinder it is inferior to the tube-mill unless operated in connection with an air separator, in which case its position is uncertain, while as a coarse grinder it is undoubtedly superior.

There are very wide variations in the designs of these machines; for example, there are two main types, in one of which the rollers are driven while the pan remains stationary, and in the other the pan is rotated. This latter type is the one most usually employed in the cement industry. It consists of a cast-iron pan secured to a vertical shaft which is supported at its lower and upper end in bearings situated in the frame of the mill. The bottom of the pan is armoured with chilled cast-iron plates, and round these a number of perforated plates are arranged. Beneath the pan, scrapers, which travel round the annular collector, are secured. The rolls are formed by securing chilled cast-iron or manganese steel rings to heavy cast-iron bosses, whose centres are bored out so as to pass over the axle which is secured at each end in slides, which permit of the axis of the rollers moving in a vertical plane. The material is fed into the pan in front of one of the rolls, and after passing beneath it, scrapers direct the crushed material to the perforated plates, after which another set divert it into the path of the second roller, and so on. The fine material passes through perforations into the annular receiver, the scrapers in which convey it to the outlet chute. A casing is often provided to prevent the dust formed in grinding being disseminated through the mill-house.

The following figures give the leading dimensions, outputs, &c., of this class of mill, which is illustrated in Fig. 32 :—

Diameter of rolls - - - - -	3 ft. 3 in.	5 ft.	6 ft. 6 in.
Width of rolls - - - - - -	12 in.	16 in.	20 in.
Weight H.P. required - - - -	4 in.	8 in.	12 in.
Output passing $\frac{1}{4}$-in. ring, limestone -	1 ton	4 tons.	10 tons.

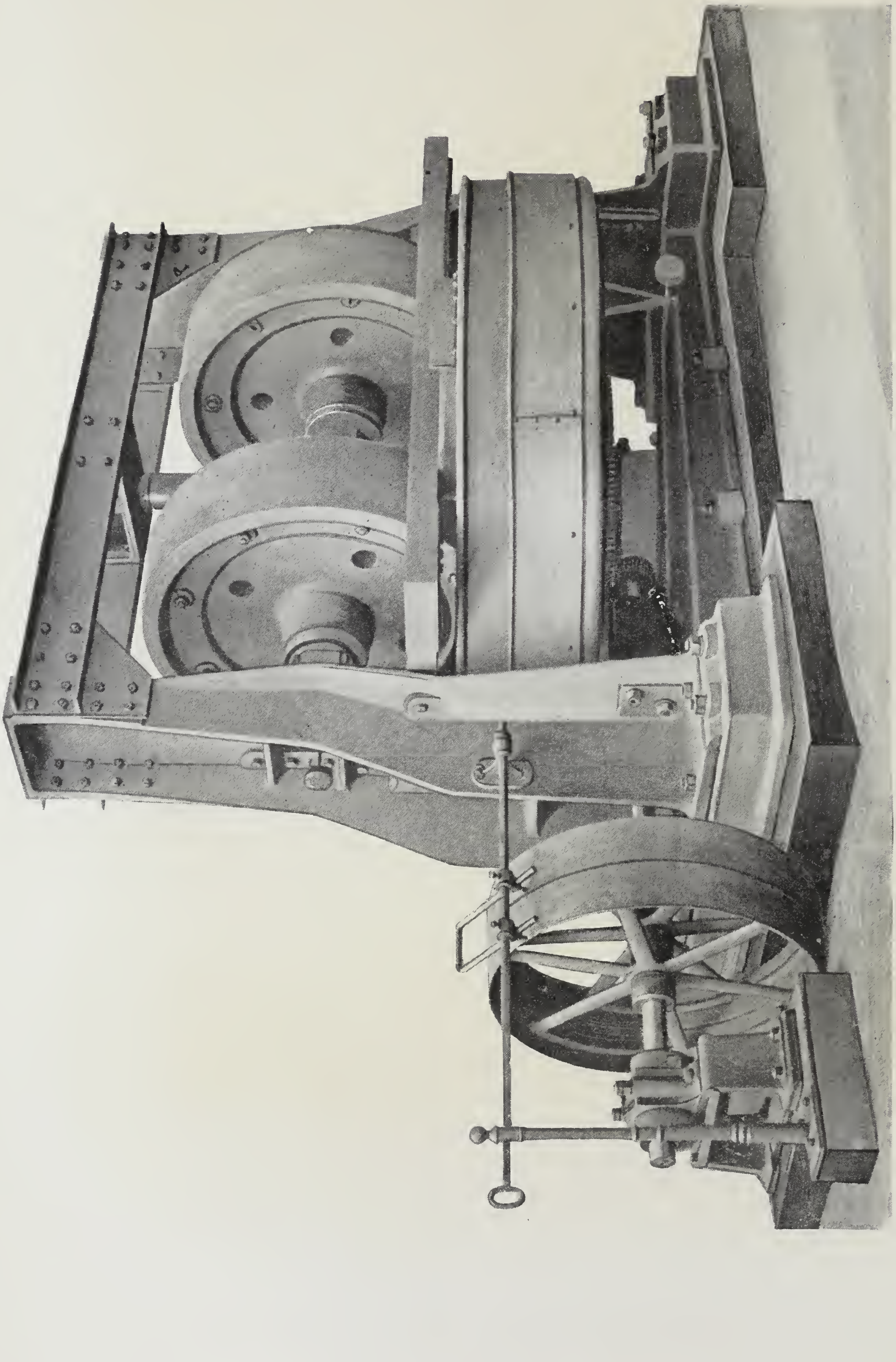


Fig. 32.—Under-Driven Edge-Runner.

An output of 6 tons per hour is given for a dry pan reducing shale in lumps up to 4 by 8 inches to pass $\frac{1}{8}$-inch sieve, the power consumed being 20 horse-power.

The product of the edge-runner with screen plates, having holes $\frac{1}{4}$ inch in diameter, is suitable for further treatment in roller mills preparatory to finishing in tube-mills, or it may be fed direct to a mill of the pendulum roller type or a centrifugal ball-mill and there finished in one operation.

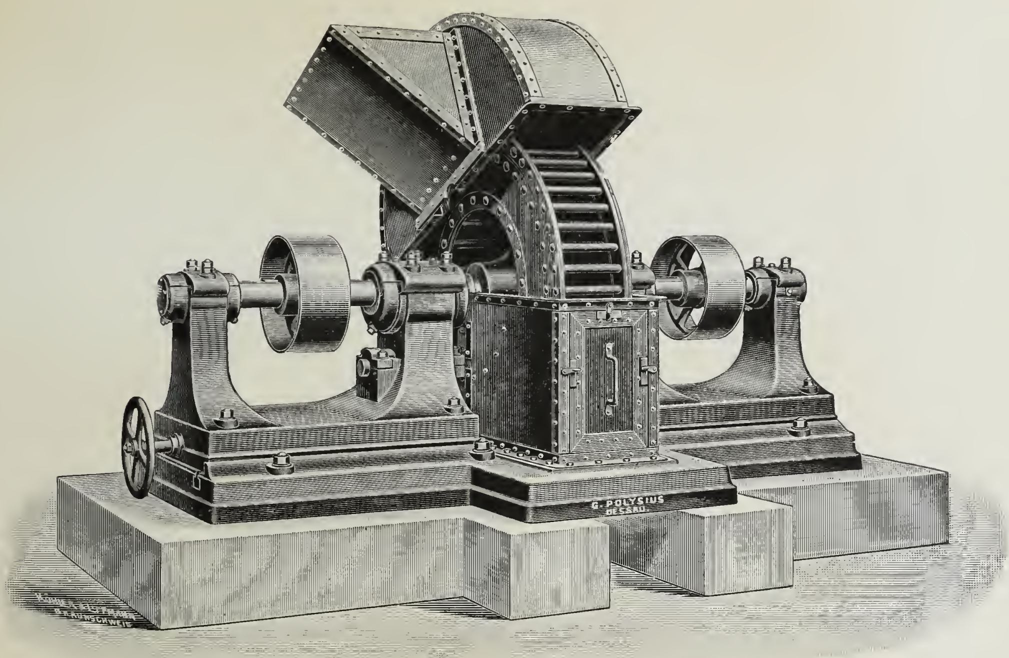


FIG. 33.—Bar Disintegrator.

The edge-runner, however, in the most modern plants is followed by a roller mill. For example, this arrangement has been adopted at the Portland Cement-Fabrik "Rudelsburg" and the Portland Cement-Fabrik "Anna."

A machine which is well adapted for reducing to grit lumpy material of a friable nature as it comes from the crusher is the disintegrator. This machine, illustrated in Fig. 33, consists of two sets of bars, each being arranged in two or more concentric circles. The diameter of these circles

is such that the two discs can be rotated in opposite directions, the second and fourth rows of bars turning in one direction, and the first and third in the opposite.

The material is fed into the centre of the mill and is thrown outward by centrifugal force. Passing the first row of bars it comes into contact with the second which is moving in the opposite direction. It thus passes in a zigzag manner

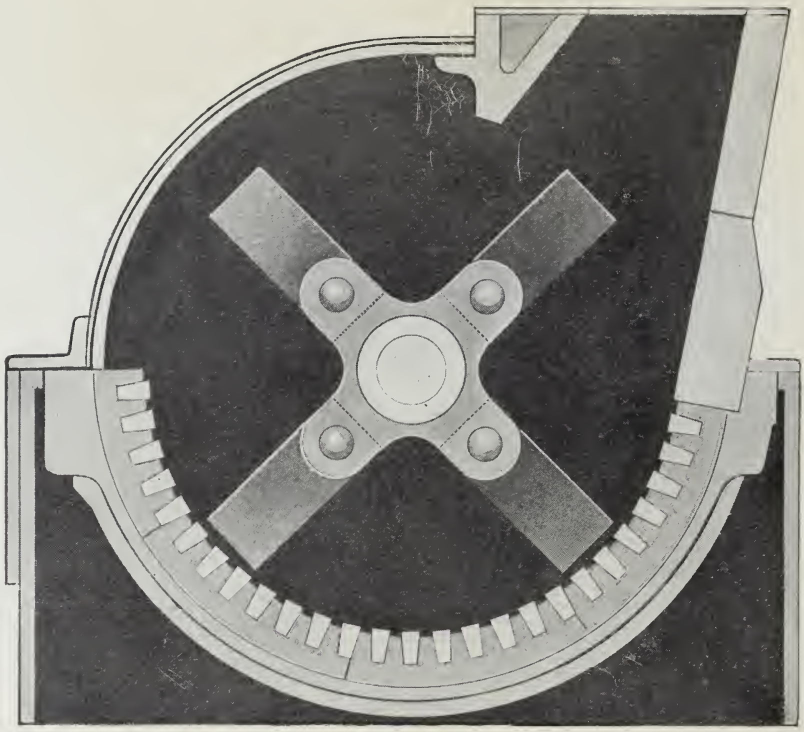


Fig. 34.—Section of Jeffrey Pulveriser.

from the centre outwards. Each shaft is journalled in two bearings, and one pair can be slid outward, taking the cage with it, for inspection or repairs.

A dust casing surrounds the cages which serves to collect the ground material.

The capacity of the machine depends upon the number of bars and on the nature of the material to be ground.

The speed at which the cages are driven is very high, and

the wear and tear is considerable if the machine is operating on hard material.

Although adopted for the reduction of substances having widely varying properties, it is most suitable for the treatment of the more friable materials. It has been employed in several works for pulverising clay.

The Jeffrey pulveriser is a type of machine which in its action somewhat resembles the disintegrator just described. This machine is shown in section in Fig. 34. The material to be ground is fed into the grinding chamber by the chute on the right-hand side of the machine, and the spider to

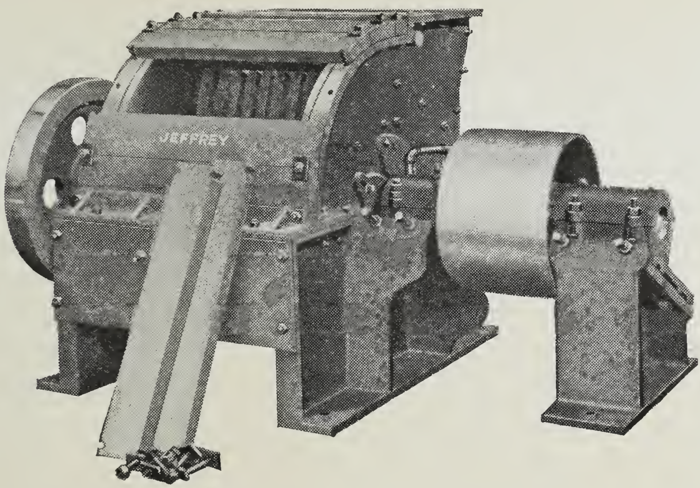


Fig. 35.—Jeffrey Pulveriser showing Sectional Casing and Sliding Bearings.

which the hammers are secured is rotated in a clockwise direction so that the material is caught and driven against the breaker plate. When reduced sufficiently to pass the grating which forms the bottom of the machine, it drops through into a hopper from which it is led to the finishing mill. This machine is capable of dealing with all kinds of material such as are used for the manufacture of Portland cement, and when provided with steam heating it can be employed for grinding clay or shale in their naturally moist condition. The bearings for the spider spindle are arranged on an inclined plane so that the hammers can be brought nearer to the breaking plate and screen so as to compensate for wear.

The screens are built up from bars spaced in racks, but in certain cases cast-steel grates are employed, the bars inclining toward the centre, forming a V-shaped arrangement. The constructive details are more clearly shown in Fig. 35.

When employed for finer grinding, the grating is placed at the top of the mill, and a fan is provided which extracts the finer particles, the coarser dropping back into the grinding chamber. The fine particles are led to a settling chamber such as the "Cyclone."

Very similar in design to the mill just described is the Williams mill, with regard to which Eckel states that a chemist gave him the following actual working results. Three Williams mills were operating on limestone and shale which had passed a Gates crusher and averaged $1\frac{1}{2}$ inches in size; each mill consumed 18 horse-power, and the product from them gave the following residues :—

Mesh of sieve, holes per lineal inch - - - - -	20	50	100	200
Per cent. of residue - -	25	45·1	60·7	69·5

The output was sufficient for the production of a thousand barrels of cement per day, that is to say, each mill would grind approximately 3 tons of raw materials per hour.

The manufacturers of the Jeffrey give the following figures with regard to output and power consumption :—

Diameter of Hammer Circle.	Inside Width.	Limestone.		Coal to 80 to 100 mesh.	
		Power.	Output.	Power.	Output.
In.	In.	H.P.	Tons.	H.P.	Tons.
24	18	12 to 15	1	10 to 15	$\frac{1}{2}$
30	15	15 ,, 20	2	12 ,, 15	$\frac{3}{4}$ to 1
30	24	20 ,, 25	3	15 ,, 20	1 ,, 2
36	18	25 ,, 30	4 to 5	15 ,, 20	2 ,, 3
36	24	35 ,, 40	6 ,, 8	...	...

In certain cases this class of mill has been used for the reduction of clinker, but the wear and tear under such circum-

stances becomes considerable, and the output is much smaller than when working on limestone and softer material; the correct position of such mills, therefore, is as a grinder of soft to medium hard substances.

The following figures show the character of the product obtained by grinding blast furnace slag in the Jeffrey mill with racks spaced $\frac{1}{16}$ inch apart :—

Holes sieve per lineal inch	180	120	100	76	50	30	20	10
Per cent. residue - -	89·0	80·4	74·8	69·0	54·0	30·0	14·4	2·0

A mill which has been largely employed in conjunction with the edge-runner, for turning out a product to be subsequently finished in a tube-mill, is the roller-mill.

The product of an edge-runner contains a quantity of material too large to be further reduced in a tube-mill, and the roller-mill is equally unsatisfactory when employed in reducing a feed which contains pieces widely differing in size to a fairly uniform product.

The former mill can be so arranged as to produce a feed suitable for the roller-mill, and by means of it a suitable feed for the tube-mill can be prepared.

The roller-mill is most suitably employed in the reduction of moderately hard material; and it has therefore been employed in the cement trade for grinding raw materials and coal. It consists of a pair of feed rolls which deliver the material to be ground at a uniform rate to the grinding rollers. These are of different diameters and are rotated at different peripheral speeds, by which means a rubbing as well as a crushing action is obtained. The rolls are turned up to a true face and the larger is driven by means of a pulley from the line shaft while the smaller is driven from it by means of spur wheels.

CHAPTER V

BALL-MILLS

In a subsequent chapter, certain mills will be described in which balls are employed for grinding materials of various kinds; they may, therefore, be described as ball-mills. But as the term is usually applied, a machine of entirely different construction is covered by such a description. The ball-mill is a drum rotated about a horizontal axis, the interior surface of the drum being so formed that it consists of a number of steps. The drum contains a certain number of balls which roll and fall from step to step crushing and grinding the material fed in.

The constructional details of these machines as made by different manufacturers vary considerably, and only those which are most extensively employed will be described. As manufactured by Messrs Krupp and certain other firms, the drum is formed of two circular wrought-iron side plates one of which is secured to a blank and the other to a spider hub, each of which is keyed to a horizontal shaft and at a certain distance apart. Between these two side plates a number of tough cast-steel plates are secured by bolts, the plates being so arranged as to form steps. These grinding plates are thicker at the edge nearer the centre of the mill than at the outer edge, toward which a number of rows of holes tapering from the outer to the inner side of the plate are provided. Around the grinding drum a screen of perforated or slotted steel plate is arranged, and between the steps narrow strips of perforated plate are secured. Arranged behind these coarse screens, sieves formed of slotted plate or woven wire are provided.

Upon rotating the drum, the material fed in at the spider nave is crushed and ground by the falling balls, and passing through the holes in the grinding plates falls upon the coarse

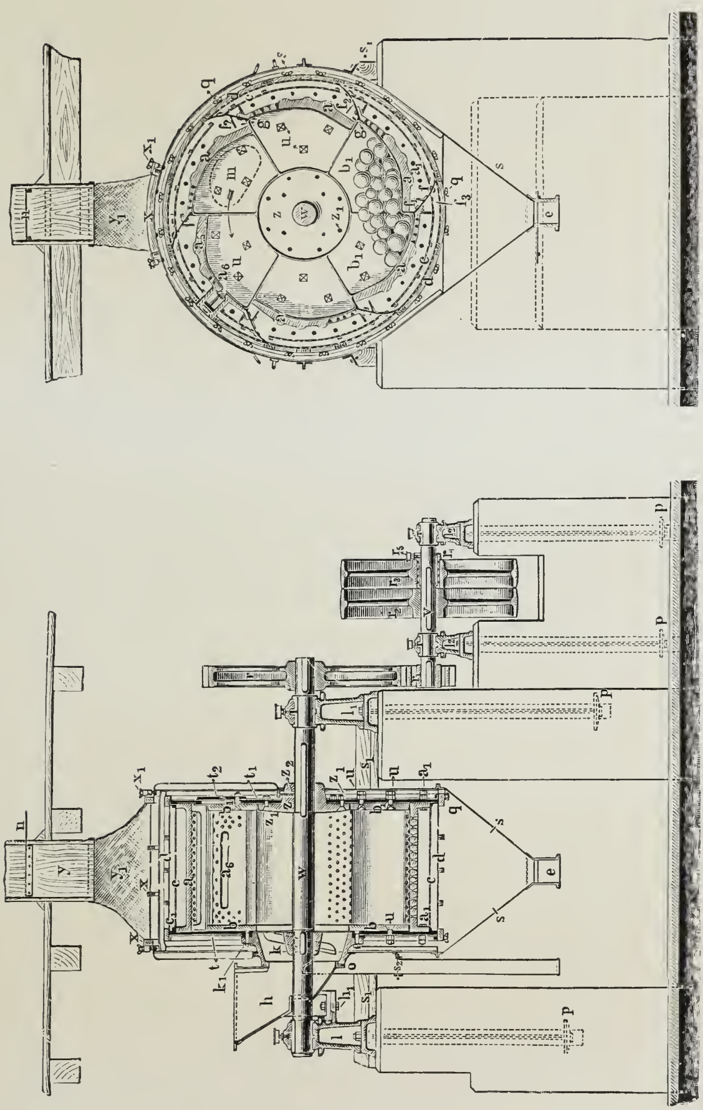


Fig. 36.—Section of Krupp Ball-Mill.

sieve. The material which is fine enough to pass this falls upon the fine sieve, and that which is sufficiently reduced in size falls through into the sheet-iron casing surrounding the mill. The tailings from both series of sieves returns to the grinding drum as it rotates, and are further reduced; this operation proceeding continuously so long as the drum is rotated and material is fed in.

Some manufacturers connect the side plates by means of mild steel plates and armour these with chilled iron, tough cast steel, or manganese steel sectional grinding plates. This system possesses the advantage that one man can handle the sections, and that the sections near the centre of the mill, which wear most rapidly, can be removed and replaced

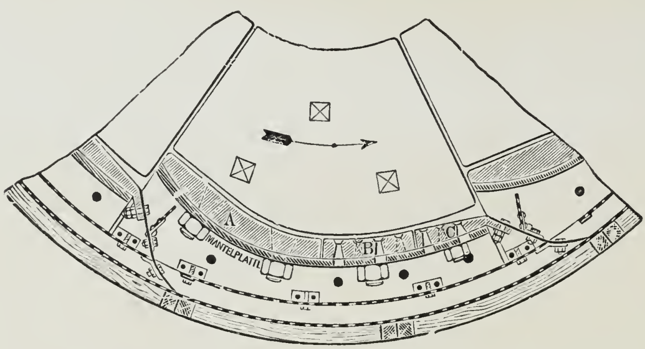


Fig. 37.—Method of securing Armour Plates to Skin Plates.

without throwing out the whole plate as would be necessary in the other case. In certain instances Krupp ball-mills have been provided with special tough plates in sections secured to cast-steel skin plates, as shown in Fig. 37. The difficulty with this system is the shearing of the bolt-heads, due to the hammering of the plates. This has been overcome by Messrs Löhnert, who have devised a system for securing the plates which was described at the 1907 meeting of the Verein deutscher Portlandzementfabrikanten. According to this system, the holes in the grinding plate are made conical, and the bolt-heads hemispherical. The holes in the skin plate are sufficiently large to take the stem of the bolts securing one end of the plate, while for the others, slots are provided which permit of the bolt moving toward or away from the fixed

bolts. Beneath the nuts, domed steel spring washers are placed and the nuts tightened up. By this means the plate is allowed sufficient play to render almost impossible the shearing of the bolt-heads. Another system of securing the cast plates is shown in Fig. 39.

The side plates in certain cases are polygonal in shape,

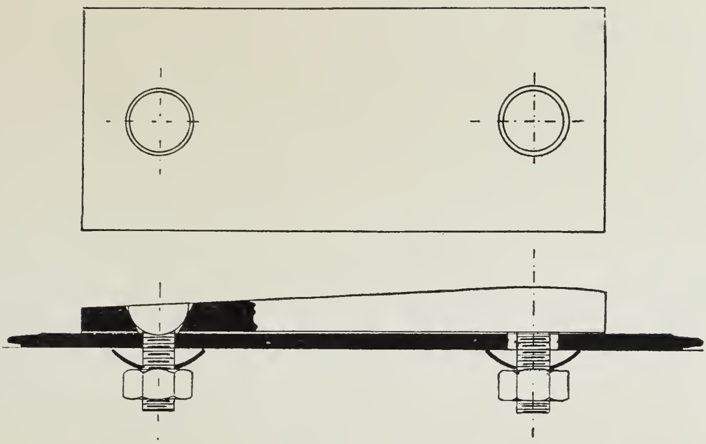


Fig. 38.—Löhnert System of securing Lining Plates.

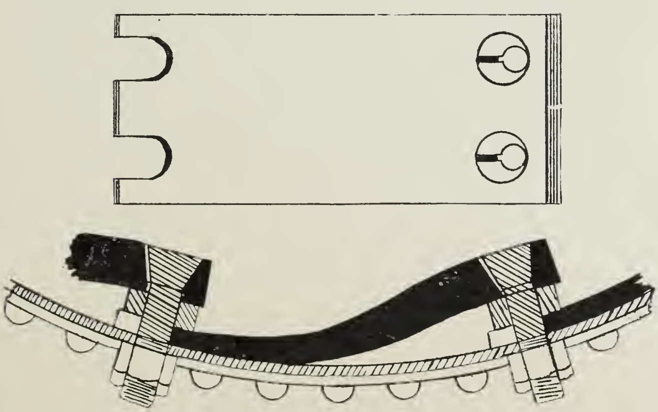


Fig. 39.—Smidth System of securing Lining Plates.

and the fine sieves thus form the sides of a prism of polygonal section. By this arrangement the material falling upon them is given a jigging motion in place of the merely sliding action with cylindrically arranged sieves. Arranging the sieves to form a series of steps, much in the way the grinding plates are set, has a similar result.

The grinding drum of a Jenisch ball-mill which is constructed on this principle is illustrated in Fig. 40. In operation it is similar to the Krupp mill, but the fine sieves instead of being cylindrical form the sides of a polygon.

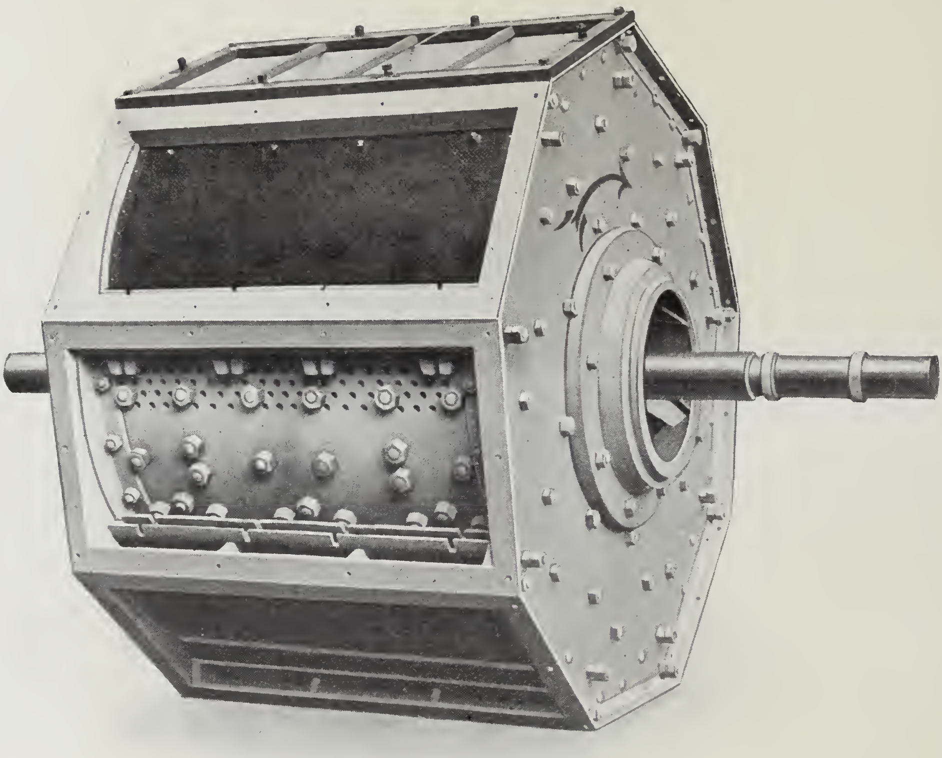


FIG. 40.—Drum of Jenisch Ball-Mill, showing arrangement of Sieves, &c.

The following particulars of the principal dimensions of ball-mills are tabulated below :—

Size.	III.	IV.	V.	VI.	VII.	VIII.
Diameter of drum in mm. - - -	1,100	1,400	1,600	1,980	2,200	2,650
Width of drum in mm. - - -	840	950	1,120	1,300	1,460	1,700
Weight-balls - -	3·5 cwt.	7 cwt.	12 cwt.	24 cwt.	36 cwt.	50 cwt.

It will have been observed that in both of the foregoing ball-mills the tailings from the screens are led back into the drum, and pass over the perforated plates almost immediately after their re-entry. They will therefore, in great part, return to the screens, having undergone but little further reduction in size; the result being that there will be considerable unnecessary wear upon the screens. Again, the area of screening surface on to which the partially ground material comes through the holes in one section of grinding plates, or one step, is only one-tenth of the whole area covered with sieves, before it is returned to the drum. The period during which it is in contact with the sieve does not exceed the time taken for the drum to pass through one-third of a revolution, and therefore is approximately one-second. To obtain a better screening and grinding effect the material is forced in some types of mill to travel right across the drum before being discharged on to the sieves, with which it remains in contact until it has either passed into the dust casing or has travelled back to the feed side of the mill if it is too coarse; the tailings, in turn, having to re-traverse the drum before being again discharged on to the sieves.

The Kominor, illustrated in Fig. 41, is one of the best-known mills of this type. The body of this machine consists of a cylinder formed by bending a mild steel plate and butt riveting the edges; the end plates are formed of steel and are riveted to the cylinder. This body is secured by means of cast-steel naves to a shaft passing through its centre. The grinding surface is formed of cast-steel step plates bolted to the shell, and the side plates are also armoured. At the feed side an annular plate is secured, and to the opposite end a similar ring is bolted, but it is of smaller diameter. At the larger end three C-formed return chutes are provided which collect the tailings from the screens, returning them to the drum. The sieves, coarse and fine, form the frustum of a cone and the material discharged on to them by the ports at the side opposite the feed end passes back towards the feed side, the tailings being returned by means of the chutes. The grinding plates are of convenient size for handling by

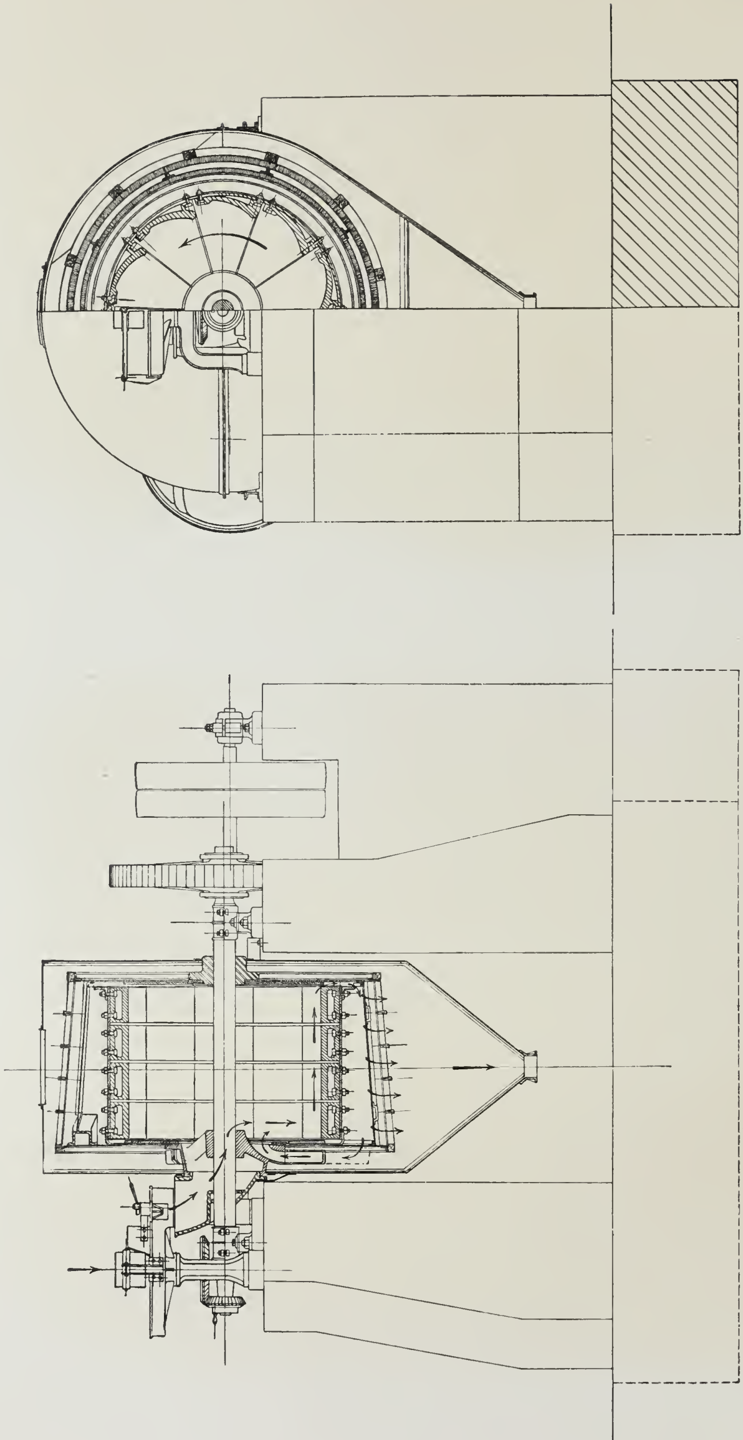


Fig. 41.—Smidth Kominor.

one man, and can be passed in or out through the manholes provided in the end plates. The ports which have been previously mentioned are openings arranged round the periphery of the drum by which the material passes to the sieves. These ports may be closed by covers and the amount of material passing into the sieves may be regulated to a large extent in this manner.

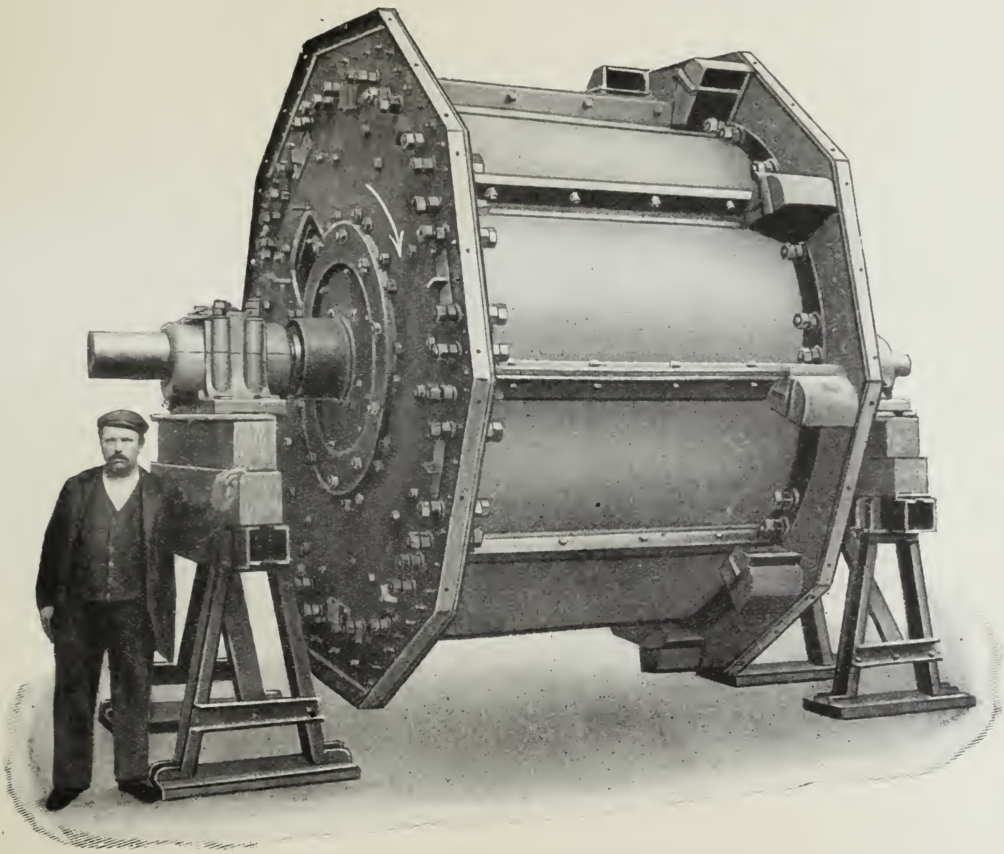


FIG. 42.—Grinding Drum of Cementor, showing Return Pockets.

The mill is driven by a spur wheel and pinion, and the body is surrounded by a dust casing as in the previously described ball-mills.

Another mill operating in a similar manner to the foregoing is the Cementor. The drum is formed of two polygonal wrought-iron side plates which are connected by

grinding plates arranged so as to form a series of steps. These grinding plates are made of tough cast steel and each step is formed of one plate. The drum is secured to the central shaft by means of naves in the usual manner. At the side opposite the feed, a number of openings are provided which are protected from the action of the balls with which the mill is charged. These openings can be closed by means of stopper plates, and the amount of material passing on to the screens may thus be regulated. The ground material from the drum passes on to the sieves, of which there are two series, coarse and fine, and passing over them the finer particles fall through, while the coarser travel towards the feed side of the mill where they are returned to the drum by means of scoops opening beneath the steps of the grinding plates. Both sieves and screens are provided with a number of carriers of L section set obliquely to the edge. The function of these carriers is to cause the material to travel to the returns. The sieves are arranged prismatically so that a jigging motion is imparted to the material, thus increasing the sieving action and aiding in dressing the sieves. The ball-mill, as usually employed, is required to produce a grit which will pass the 20-mesh sieve, but the proportion of flour to the various sized particles of grit varies considerably. The following figures, however, give a fair idea of the grading of the product of a ball-mill :—

Sieve - - -	120	100	76	50	30	20	10
Residue per cent. -	56	50	42	30	14	2	0·5

The quantity of material fed into the mill should be sufficient to deaden without muffling the sound of the falling balls. With practice the correct load can be easily ascertained from the sound, which should never be of a metallic, ringing timbre.

The fine sieve with which the mill is clothed is, as a rule, 16 or 20 mesh wire, or slotted steel plate sieves are employed, the slots being about 1 millimetre wide and 10

millimetres long, in which case the screening effect approximates to that obtained with 20-mesh wire. The life of slotted steel plates is greater than wire sieving, but, at the same time, the effective screening area is much less. The former, however, withstand brushing, which is necessitated when slightly moist materials are ground in the mill, to a much greater extent than do the latter.

With ball-mills of the foregoing type it is necessary to remove both the fine sieves and the screens when it is required to change or repair a grinding plate. Messrs Smidth now construct a modified form of their Kominor which obviates this. The mill is illustrated in Fig. 43. In this case the sieves are of cylindrical form, the coarse and fine sieves being arranged concentrically, and are connected with the ports and returns in the manner illustrated. This construction naturally leads to a reduction in the cost of repairs, while inspection of the bolts securing the grinding plates is a simple matter.

The fine sieves on this type of mill are a source of some inconvenience, and many attempts have been made to dispense with them, and mills are constructed in which they are absent. The ball tube-mill, manufactured by the Power and Mining Machinery Company, is a machine of this type. It is, in effect, a shortened tube-mill lined with step plates, and provided at its outlet end with a perforated diaphragm which serves to prevent the exit of large pieces of material and to retain the balls. This mill is employed in a similar manner to those already described in this chapter, for preparing raw material, coal, and clinker for subsequent reduction in fine grinding-mills.

Fine sieves are also absent from the Molitor ball-mill and the Molitor ball tube-mill. The former is employed for reducing to grit the softer materials, while the latter is more suited for the treatment of such difficultly ground material as rotary clinker.

The Molitor ball-mill is constructed on similar lines to the Jenisch ball-mill, but as previously stated it is without sieves. The two wrought-iron side plates are secured to the central shaft by means of cast-steel hubs. The sectional

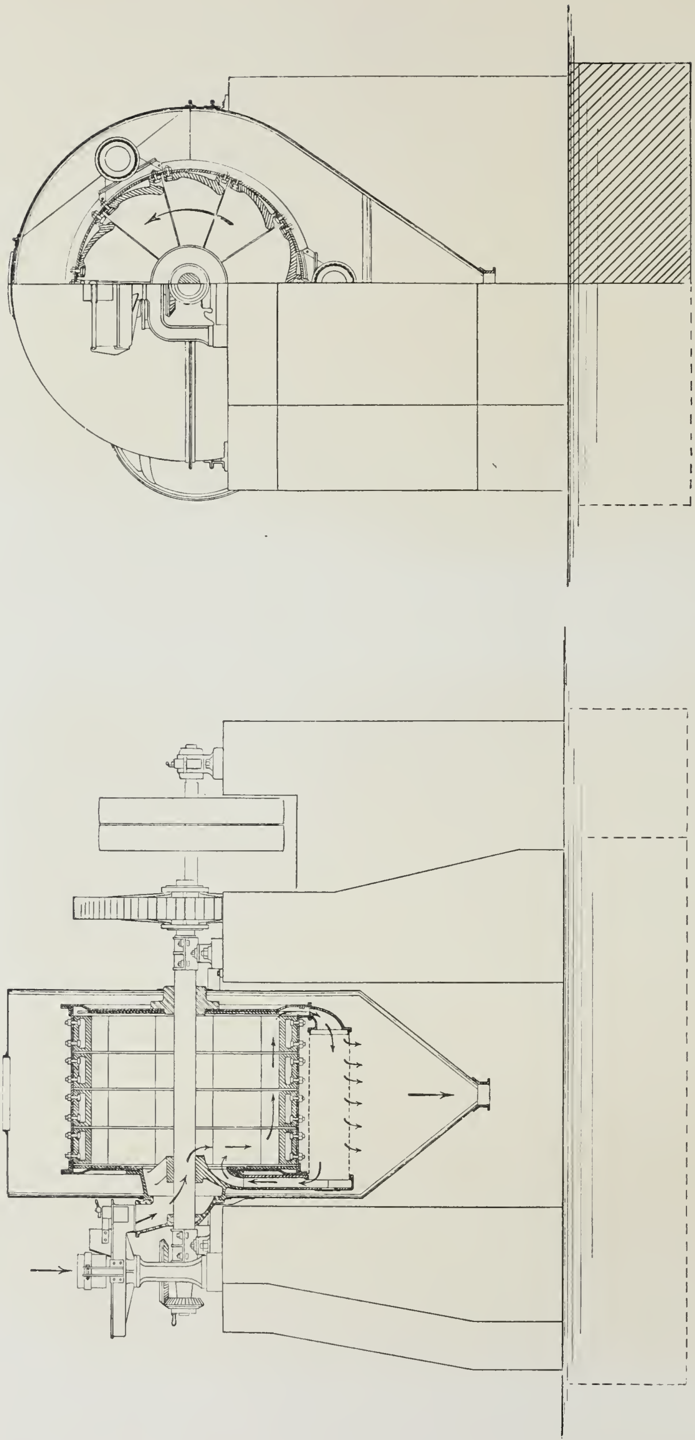


FIG. 43.—Kominor Fasta Mill.

grinding plates of tough cast steel are secured to mild steel skin plates, and the ground material is discharged from the grinding drums by means of gratings arranged between the steps. The fineness to which the product is reduced may be varied by varying the size of the grating by altering the distance between the steel bars forming the grids. The length of the grating can also be varied, thus compelling the material to remain longer in the drum before reaching the grids. This mill is not adapted for grinding very hard material, such as rotary kiln clinker.

The Molitor ball tube-mill more (see Fig. 45) closely resembles a tube-mill in design, but is shorter. It is formed by securing two cast-steel end plates each cast in one piece with a hollow trunnion, to a welded wrought-iron cylinder. This cylinder is lined with step plates, and the material, fed into the rotating cylinder through one of the hollow trunnions, travels the whole length of the mill, and then discharges on to a screen arranged concentrically to the grinding drum. This screen is surrounded by a dust casing which collects the fine material; the coarse stuff retained by the screen being returned to the drum at a point about one-third of the length of the drum from the discharge end. The mill is driven by means of a pinion engaging with a split spur secured to the end plate at the feed end of the mill. Other firms are also supplying a mill for small outputs, which is in principle a combination of the ball-mill with the tube-mill. The tube is then divided into two sections by a diaphragm. In the first section the grinding plates form steps, and the balls are large, while in the second the lining and balls are similar to those ordinarily employed in tube-mills. The ball-mill is, in certain cases, employed for the production of a finished product of a meal-like degree of fineness without any further treatment of the material in a fine grinding-mill. Under such circumstances, the use of some form of apparatus for separating the fine material from the coarse, which is present in the ball-mill product, is necessary. Woven screens, slotted or perforated plates, cannot be used successfully to this end in cases where the material to be treated by them contains a considerable proportion of grit of medium fineness,

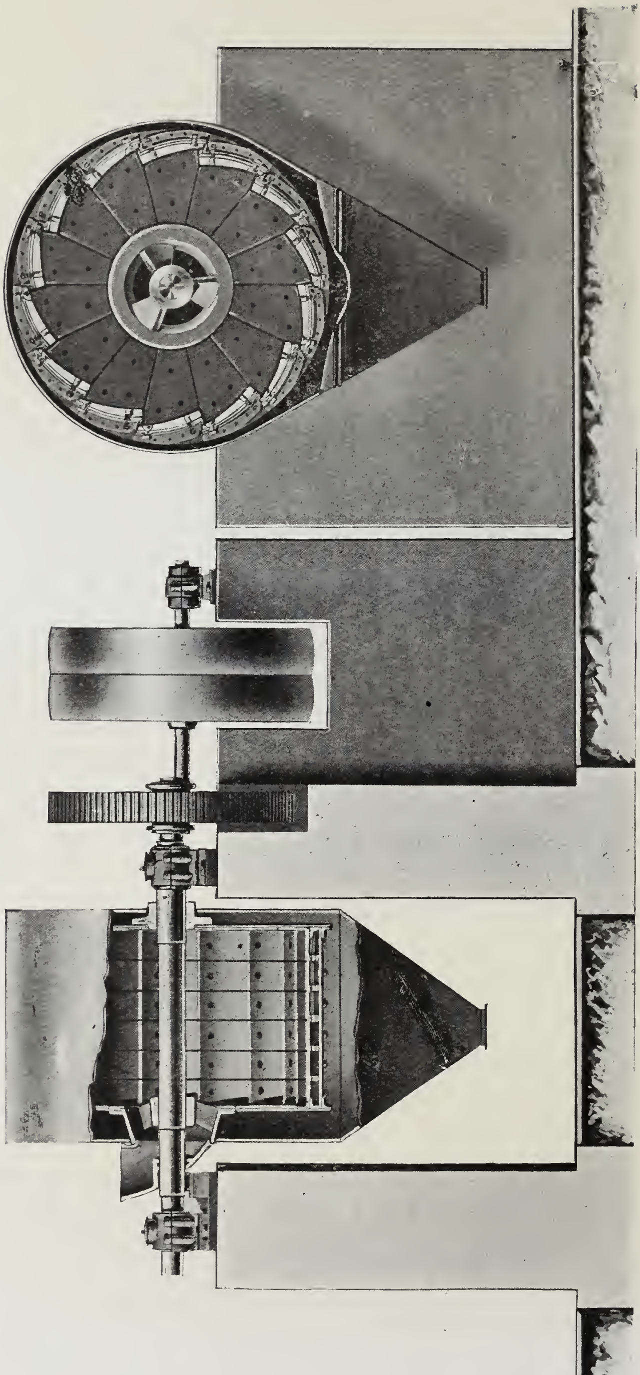


FIG. 44.—"Molitor" Ball-Mill.

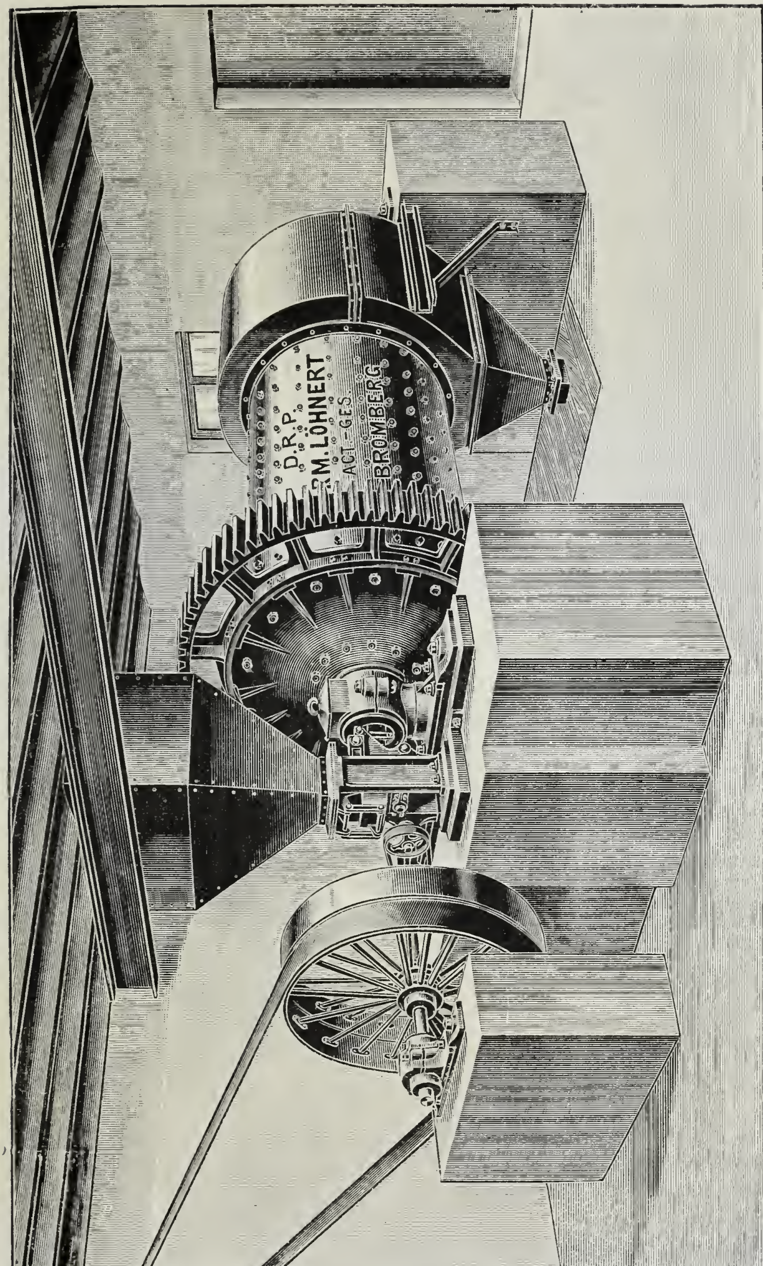


Fig. 45.—"Molitor" Ball Tube-Mill.

i.e., between, say, the 76 and 180 mesh sieves. The product of a ball-mill contains a large proportion, about 30 per cent., of such grit, and its treatment by sieves of this type is impracticable commercially. The air separator, patented by Mumford and Moodie, is admirably adapted for such a purpose, and in conjunction with a sieveless ball-mill, it has been employed with considerable success, even on the hardest material.

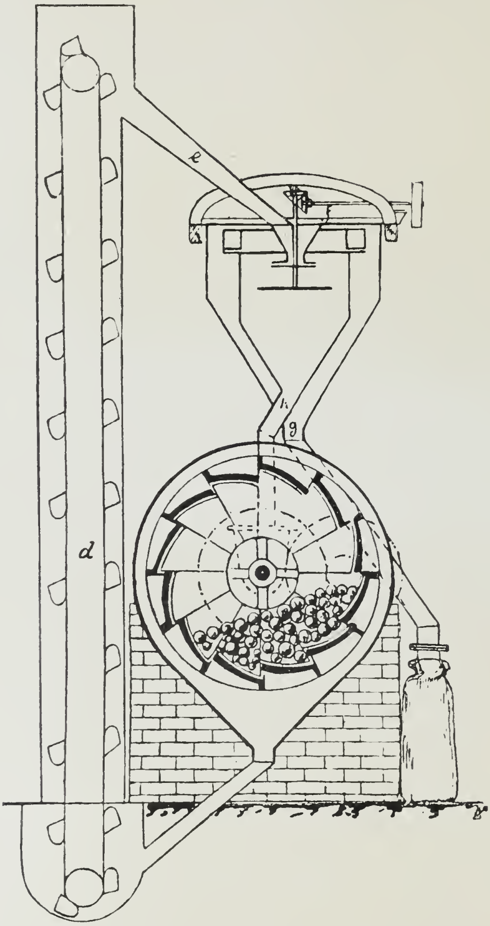


Fig. 46.—Arrangement of Ball-Mill and Air Separator.

Messrs Pfeiffer introduced such a combination which is illustrated in diagram form in Fig. 46. The material is taken from the hopper-shaped bottom of the dust casing, and elevated to the separator, on to the spreader of which it is discharged, and the fine particles are separated from the coarse by means of the air current set up by the fan secured to the central spindle. The fine material is collected in the outer chamber, and passes by way of the chute to the silo.

CHAPTER VI

CENTRIFUGAL ROLL-MILLS

The process of reducing material by means of rollers is one of the earliest systems of grinding employed. It has been extensively used in various industries and upon materials so diverse in physical characters as soap, rubber, grain, and rocks. Adapted for grinding such widely different substances, it has suffered modifications, and has thus been divided into types which have been more especially suited to the treatment of one or other class of material. In all its various forms its action is the same: the friction between the rollers causing the material to pass between them, the pressure causing them to be cracked into smaller pieces or to be squeezed into thinner layers. Combined with the crushing effect, there is also a rubbing action due to the tendency of the material to withstand the nipping action; sometimes this attrition is increased by rotating the rollers at different speeds.

The edge-runner mill is, of course, a roller-mill, the rotating pan acting in a similar manner to a roller of very great diameter and rotating at an angular velocity greater than the runners, the grinding pressure being due to gravity. In the machines to which the term roller-mill is usually restricted, the grinding pressure is due to springs, while in certain forms with two circular rollers the grinding pressure is due to the centrifugal action on the roller shells. In the types of mill described in detail in this chapter, the grinding pressure is due to centrifugal force applied in a different manner.

The Huntingdon Mill was the predecessor of a number of other mills which have met with extensive application in the cement industry. In this type of mill, a number of rolls are so supported as to be capable of rotation about their own

axis, and of swinging freely in a radial direction as regards the disc to which they are attached. This disc is secured to a vertical shaft rotating in a footstep and crown bearing, and driven by means of a pulley and half-cross belt. A die in the form of a ring is secured to the base of the machine. The rolls, which are provided with hardened tyres, are driven outward on rotating the vertical shaft, and press against the die, and the material to be ground is pulverised as the rollers press it against the ring. The fine material passes through a sieve, and is collected.

The Griffin Mill operates in a somewhat similar manner, but it has only one roll. This roll is secured to a spindle screwed into a sphere provided with two trunnions. These trunnions are connected with the pulley by means of sliding bearings. On rotating the pulley, which is supported in the peculiar form of bearing shown, the roll is rotated and can be swung freely in any direction. The bearing and universal joints are supported by a framework constructed of timber and cast iron strengthened with wrought-iron tie-rods above a cast-iron base, the centre of which forms a basin. The die ring, which is tapered from its centre upward and down, is held in place by means of a pressure ring, above which a cylindrical casing is arranged. Above the grinding chamber a cylindrical sieve is arranged. This sieve is surrounded by a dust casing, a cast-iron ring, and a truncated conical shield, closing over the whole of the grinding and sifting chamber. The material is fed into the mill by means of the worm driven by a small belt from the stepped pulley above the main pulley, and, falling into the basin, is ploughed up by the projecting spurs below the roll. Coming between the roll and the ring, the material is ground and the fine particles are winnowed by the fans secured to the spindle, and passing the screen, fall by means of the channels arranged round the basin into the hopper-shaped receptacle beneath the mill. The construction of the mill is amply illustrated by Fig. 47.

In starting the mill, the roll and spindle hang vertically until it is brought against the die around which it continues to run so long as the pulley is driven. These mills must

have strong foundations, and their great point is their economy in space as compared with, for example, a ball and tube mill. The power required is from 25 to 30 horse-power

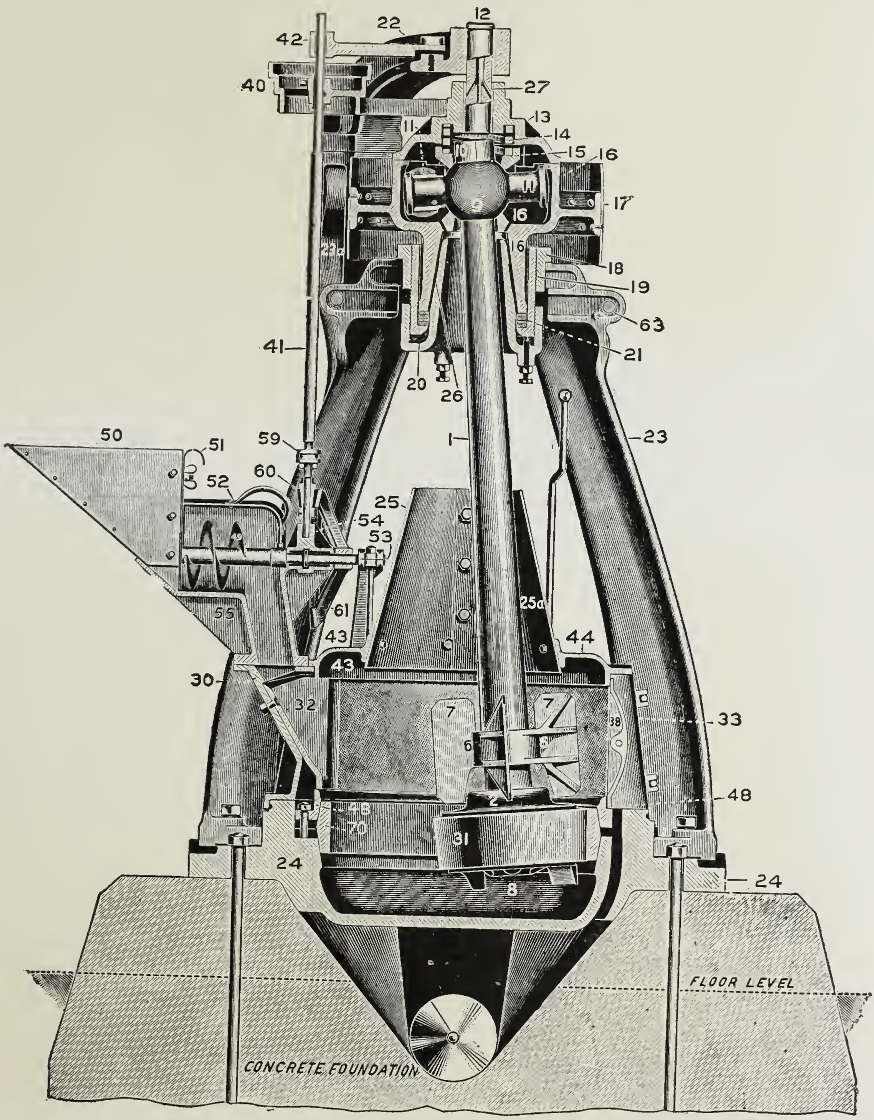


Fig. 47.—Section of Griffin Mill.

for the mill with a die 36 inches in diameter, and grinding vertical kiln clinker reduced to $\frac{1}{2}$ inch, the product leaving only 20 per cent. on the 180 sieve, the output is from 1 ton

10 cwt. to 2 tons per hour. With rotary, the output under similar circumstances is one-third less. Grinding coal, the output is from 1 ton 15 cwt. to 2 tons per hour ground, to leave a residue of 1·5 per cent. on the 76 and 20 per cent. on the 180, the output being halved when a product leaving only 10 per cent. on the 180 is produced. Grinding limestone, a similar output is obtained as when the mill is employed for grinding coal.

A somewhat modified type of this mill is manufactured by Messrs Polysius, of Dessau; the composite support for the main bearing being replaced by a heavy A-formed casting, and the driving head runs on a ball bearing. In the main, however, it resembles the mill just described.

Another modification in design is the employment of bevel gear in place of the pulley with half-crossed belt, which is employed for driving the foregoing machines.

For a number of years, mills with more than one roller have been employed, and they possess the advantage that the strains on the driving mechanism and frame are more equally distributed, and without complicating the constructive details. One of the earliest types, the Huntingdon mill, has already been briefly described. Another machine which has been in use for some years is the double pendulum mill, manufactured by Messrs Nagel & Kaemp. In this mill the basin is constructed of peculiar form, the centre projecting upward to form a support for the footstep bearing for the vertical shaft to which the driving pulley is keyed. Below this pulley the universal joints for the pendulum shafts are secured to a casting of suitable form, and lower still, guides are provided which keep the rolls and their shafts at a fixed angle the one to the other, while permitting of their motion to and from the centres of the mill. The feed of the material to be ground, and the discharge of the finished product, is obtained in a manner substantially the same as the pendulum mills previously described. For the output and consumption of power of this mill Naske gives the following figures: at Hemmoor (1895), 2 tons 4 cwt. of cement with 2·3 per cent. on the 76 by 76 and 14 per cent. on the 180-mesh sieve; at Ledecz, 2 tons 10 cwt. with 2 per cent. on the 76 and 12 per

cent. on the 180, with the consumption of 50 horse-power as shown by repeated indicator cards.

The Neuss Mill, while very similar in principle, is of distinctly different design. The pulley is arranged below the pendulum suspensions, and the vertical shaft is therefore much shorter. Actually, the pulley is just clear of the top of the screen chamber and is secured to the headpiece, which forms the guide for the pendulums and a support for the fan. The rolls are secured to shafts, the upper ends of which are ball-shaped and are secured in sockets, below which they are held by bearings sliding in the before-mentioned guides. The fan is formed of a large number of vanes secured to the headpiece, which on rotation drives a current of air containing the fine particles in suspension through the sieve, depositing the material in the hopper-shaped receptacle beneath the mill. A part of the air passes back into the basin and agitates the material in it. The material is fed into the mill by means of a feed gear driven from a small pulley arranged above the main one by a belt.

The Bradley Mill, which is manufactured by the Bradley Pulveriser Company, the makers of the Griffin mill, is a three-roll mill in which the grinding pressure is due to centrifugal force. The frame is similar in construction to the previously described Griffin mill. The rolls are secured to spindles rotating in bearings supported so as to permit of them moving radially with respect to the circular grinding chamber. These swivel joints are bolted to a plate which is secured to the vertical shaft, and which is provided with vanes. The material to be ground is fed by means of a worm, driven from the small pulley arranged below the main one into a hopper at the centre of the mill. From this hopper it passes by means of chutes and is dropped just in advance of the rolls. The blades on the iron head-plate drive air into the mill when running, and the fine particles passing through the sieve are caught in a chamber below the mill. Scrapers are provided which throw up the material settling in the grinding chamber. (See Fig. 48.)

The bearings of this mill are dust-proof, and a positive

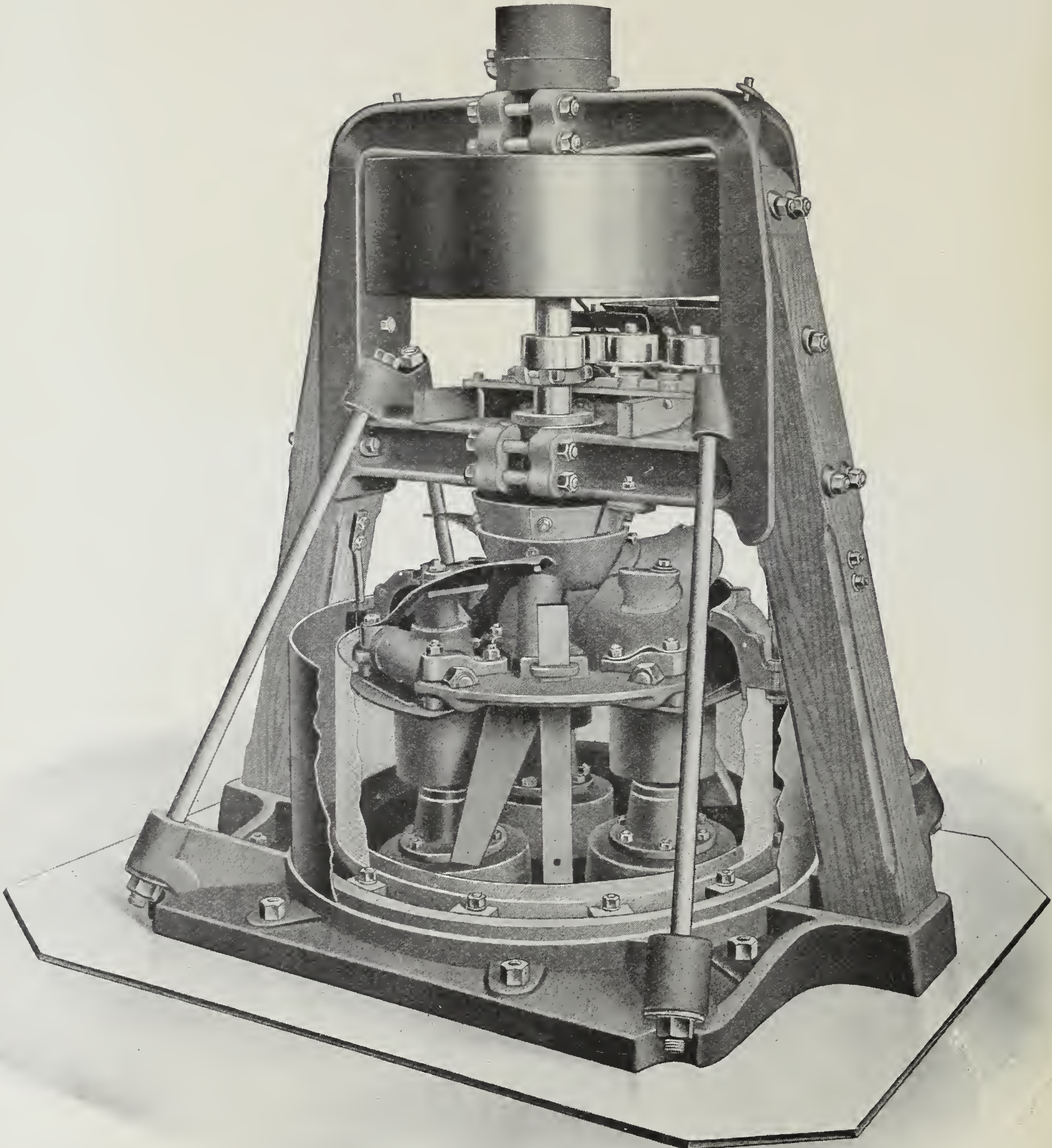


Fig. 48.—Bradley Three-Roll Mill.

lubricating system is adopted. The grinding ring is 4 feet 6 inches, and the rolls are 16 inches in diameter. The power absorbed in operating is 35 to 40 brake horse-power and it is stated that in an English works the mill is grinding from $2\frac{1}{4}$ to $2\frac{1}{2}$ tons per hour of rotary clinker, producing a cement leaving 14 per cent. on the 180 sieve. Working upon raw materials the output is from 4 to 6 tons according to hardness, the fineness of the product being 10 to 14 per cent. on the 180 sieve. When employed on coal, it will produce 4 tons of dust per hour, 95 per cent. passing the 100 mesh sieve.

The Raymond Impact Pulveriser Company are the manufacturers of a multiple roll-mill of the centrifugal type, the design of which differs considerably from those which have previously been described.

In this mill, the rolls are hung from a crown keyed to a vertical shaft which is rotated by means of a pulley and half-cross belt or by bevel wheels. A number of scoops which descend to the bottom of the grinding chamber are secured to the crown, and by its rotation they lift the material which has been delivered to the mill, feeding it immediately in advance of the grinding rolls. An air separator is arranged above the mill and the fine material is drawn upward by means of a fan, any coarse particles being returned to the grinding chamber, while the remaining fine stuff is delivered to a cyclone by means of which the finished product is separated.

The rolls in all the mills so far described have been suspended in a manner similar to the bob of a pendulum, but several other systems of suspension have been employed. For example, in Neate's dynamic grinder the rolls were spindled on shafts projecting upward from a driving disc, and in another type of mill the rolls were arranged to slide in bearing held by a horizontal cross. However, both these types are little used at the present day.

The Kent mill is a machine which, in certain respects, resembles the centrifugal roll-mill. In this mill the grinding pressure is not due to centrifugal force, but is obtained by the employment of powerful springs.

Fig. 49 exhibits the principle of its operation in diagrammatic form. The upper roll is driven by means of a pulley keyed to its shaft, and being kept in close contact with the grinding ring by means of springs the friction causes the ring to revolve. The material is fed into the mill above the roller on the right of the figure and is dragged beneath it by the rotation of the grinding ring, after which it passes beneath the second roll. The material leaves the grinding chamber by

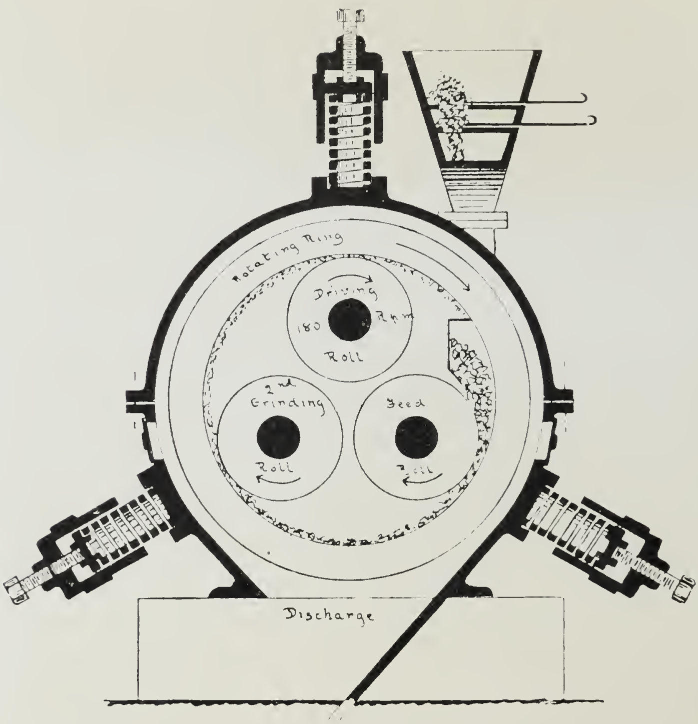


Fig. 49.—Section of Kent Mill.

an opening at the bottom of the mill. The rolls have convex faces, while the face of the grinding ring is concave; in this way lateral motion of the grinding ring is reduced to a minimum. The mill itself has no sifting arrangement and thus its product contains material in the form of nibs. It is consequently necessary to provide some sifting device to separate these coarse particles. Sieves having an inclined screening surface of wire cloth which is continuously vibrated, or air separators, are usually employed for this purpose. By

this means it is possible to obtain a product having any desired degree of fineness.

The mill can be employed for grinding raw materials, coal

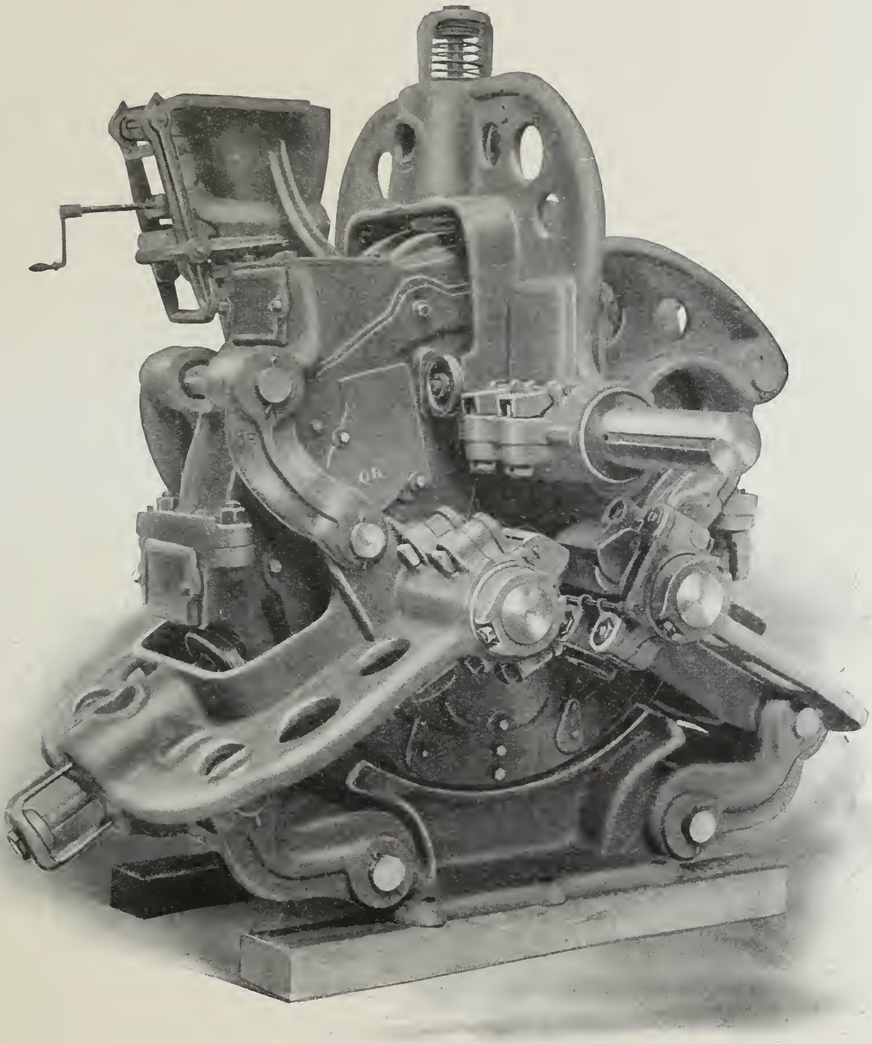


Fig. 49*a*.—Side View of Maxecon Mill.

or clinker, and it may be used as a mill for producing grit to be subsequently reduced in mills of another type, or it may be employed in conjunction with an air separator for the production of a finished product.

The power required for driving is from 25 to 30 horse-power, and its output when grinding rotary clinker is about $6\frac{1}{2}$ tons per hour reduced to pass to 20 by 20 sieve, 4 to 5 tons passing the 30 by 30 sieve, or from 2 to $2\frac{1}{2}$ tons of finished cement.

When air separators are employed in conjunction with

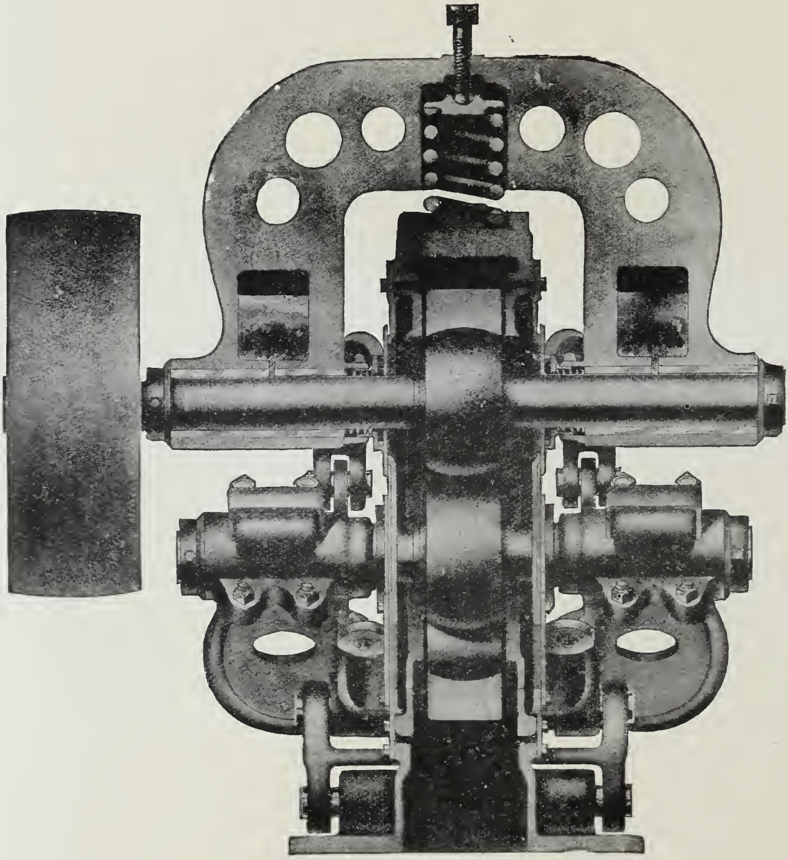


FIG. 49*b*.—Section of Maxecon Mill.

the Kent mill for the production of finished cement they are arranged in pairs discharging into a common separator having a diameter of about 9 feet. Similar plant is also employed in the coal and raw mills of several plants in America.

When the mill is used for producing grit, to be subsequently reduced in tube-mills, a vibrating separator is arranged between the Kent mill and the tube, to intercept

any large particles, and the feed to the tubes in this way is rendered fine enough to pass the 20-mesh sieve. In a particular plant the Kent mills, of which there are four, turn out a product leaving 65 per cent. residue on the 180-mesh

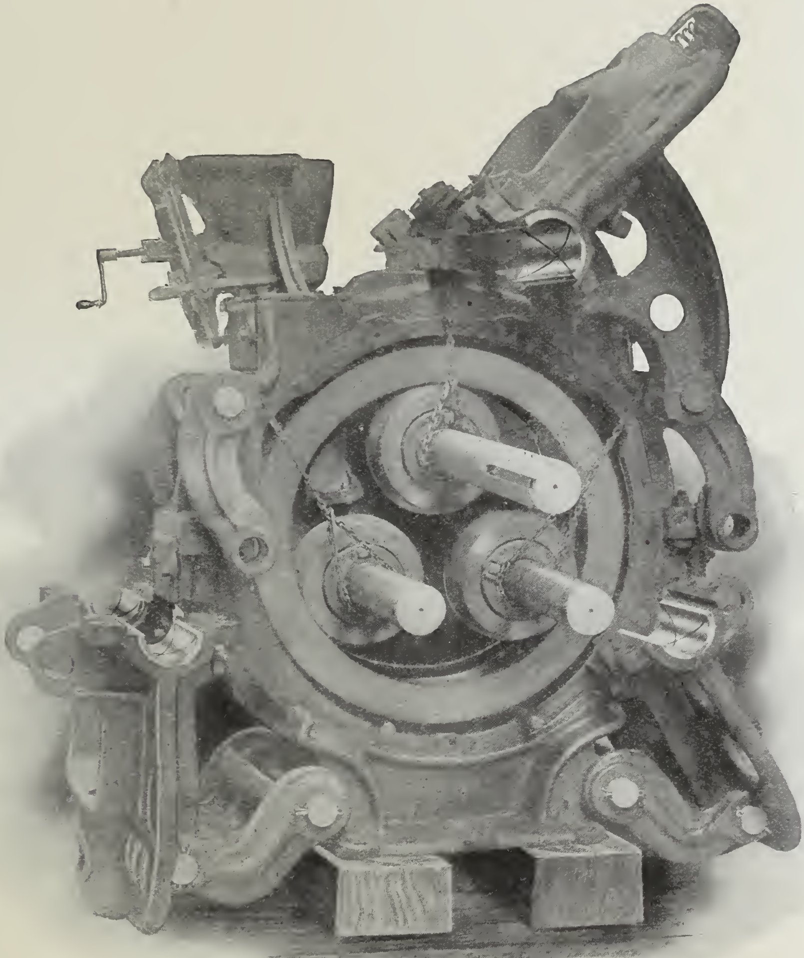


FIG. 49c.—Maxecon Mill Open for Exchanging Grinding Parts.

sieve, and 45 on the 76 at the rate of $3\frac{1}{2}$ to 4 tons per hour per mill; the grit is then fed into the tubes, which convert it into finished cement, leaving a residue of 18 per cent. on the 180 and 0·3 on the 76-mesh sieve.

An improved form of the Kent mill is the Maxecon, which, though operating on precisely the same principle, has the structural details considerably improved. The bearings are much longer and provided with removable Babbitt metal linings, and are formed in the massive cast yoke pieces, and in place of the long sliding guides for keeping the axis of the rolls in line radially with the axis of the ring, two pairs of links are employed for this purpose. The construction

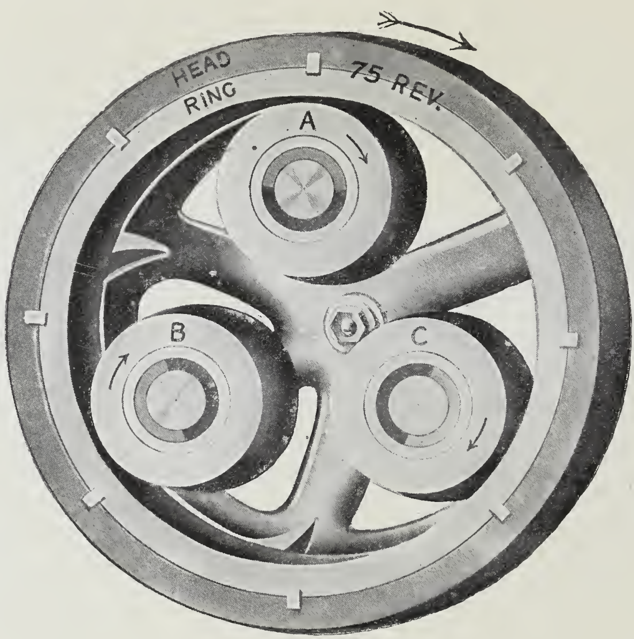


Fig. 50.—Arrangement of Rolls in Ring Roll-Mill.

and design of the Maxecon mill is well shown by the section (Fig. 49*b*), and by the illustration (Fig. 49*a*).

At the Portland-Cement-Fabrik, Rudersdorf, one of these mills is employed feeding two No. 12 (pebble) tube-mills, and the plant gives an average output of nearly $4\frac{3}{4}$ tons per hour of cement ground to a fineness represented by residues of $\frac{1}{2}$ per cent. on the 76 and 18 per cent. on the 180 sieve. The clinker coming direct from the rotary kilns.

When employed for producing finished cement in conjunction with an air separator, but without a fine grinder,

the output of the mill is $2\frac{1}{2}$ tons per hour with a power consumption, shown by an ammeter, equal to 32 horse-power.

For repairs and inspection the mill may be opened out with ease when convenient access may be had to the grinding chamber. Fig. 49c illustrates the mill thus opened out, and at the same time gives a clearer idea of the construction of the mill. The value of convenient access for repairs needs no elaboration.

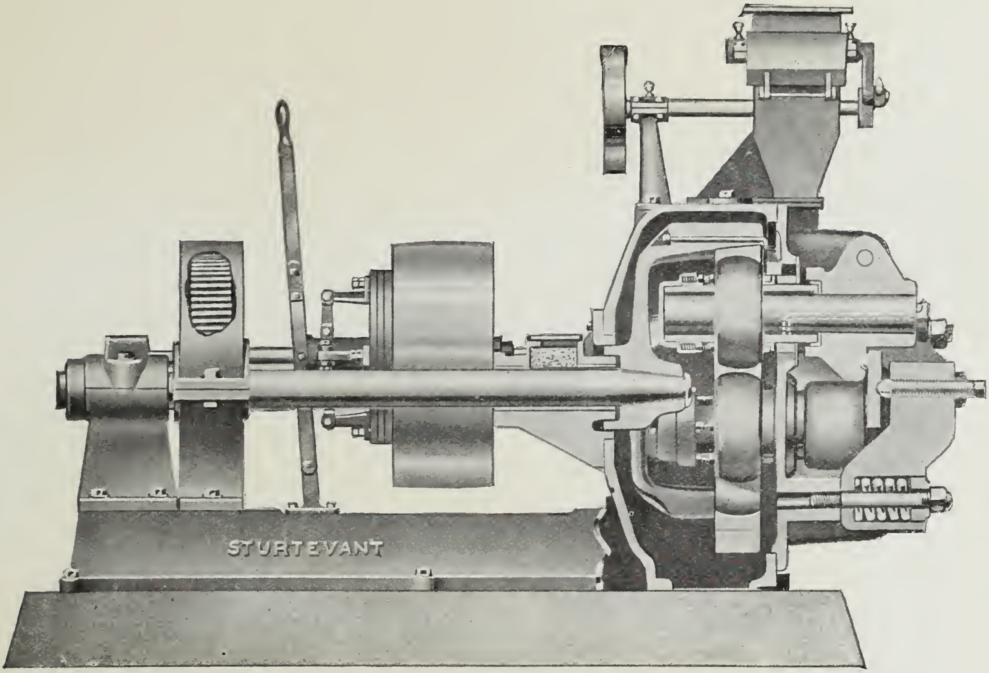


Fig. 51.—Part Section of Ring Roll-Mill.

The Sturtevant ring roll-mill operates in a somewhat similar manner to the Kent mill, but in this case the die ring is positively driven and not by means of the friction between it and one of the rolls.

The principle upon which this mill operates is shown in Fig. 50. The die ring is secured by keys to the massive cast head which is rigidly connected to the driving shaft. The rolls rotate on the spindles, and are kept in contact with the die ring by means of a spring operating through swivel joints. The face of the die ring is concave while the rolls

are convex, the material is fed in behind one of the rolls, and the rotation of the ring keeps the material on the roller path by centrifugal force, and thus causes it to travel successively beneath the rollers. The crushed material contains a quantity of nibs, and to render it suitable for treatment in the tube-mill it is passed over a separator of some form. The design is well shown by the section, Fig. 51.

The spindle to which the head is secured is driven by gearing running in an oil bath from a countershaft provided with a clutch pulley; the bearings for the countershaft being bolted to the same foundation plate as the mill itself. The convenience with which access to the interior of the grinding chamber is had, on account of the end-plate together with the rolls being supported on hinges, is a valuable feature of the design.

Another detail of considerable value is the provision of means for holding the rolls away from the grinding ring until the material has commenced feeding into the mill. The mill need therefore never run "light," thereby damaging the rolls and the die.

It is at present made in two sizes, of which the following are the leading particulars:—

	Diameter and Width of Ring.	Pulley Speed, R.P.M.	Ring Speed.	Horse-Power.
No. 1 - -	33 × 6	300	75	8-20
No. 2 - -	44 × 12	225	56	20-30

The power consumed and the output depend so much upon the character of the feed and of the product required that it is impossible to give absolute figures except for individual cases.

As an example of its output and the character of the product obtained, the following figures, obtained during a five hour test run at the works of the Coplay Cement Manufacturing Company, may be given. The mill was of the No. 2 size and operated in conjunction with two Newaygo sepa-

rators. In the five hours it ground 34 tons of rotary clinker or nearly 7 tons per hour. The fineness of the product, both before and after the screening, is represented by the following figures :—

Sieve.	Sample at Mill.	After Screening.
Holes.	Discharge Residue.	Residue.
20 per lineal inch.	58 per cent.	8 per cent.
30 ,, ,,	64 ,, ,,	20 ,, ,,
50 ,, ,,	71 ,, ,,	36 ,, ,,
80 ,, ,,	75 ,, ,,	46 ,, ,,
100 ,, ,,	78 ,, ,,	52 ,, ,,
200 ,, ,,	84 ,, ,,	64 ,, ,,

The class of mill in which a number of balls are driven in a horizontal plane round an annular die is a special type of the centrifugal roll-mill class; the grinding pressure being obtained in a similar manner, and the construction of the machines being altered only so far as is necessary to accommodate the special form of roller.

The Roulette Mill belongs to this class, and it has been employed for a number of years in the cement industry. In Fig. 52 the mill is shown in section. Its mode of operation is as follows:—The material is fed by means of the automatic feeder and chute to the centre of the mill, and falling upon the driving disc, which is rotated by means of the spindle and pulley, it is thrown outward and ground between the balls 8, which are driven by the propelling lugs 7, and the die ring, which is made in two sections, 9 and 10.

The blades 4 and 5 secured to the spider 3, secured to the spindle, form a fan which draws up the partially ground material, projecting it against the protecting sieve 11, by means of which the coarser particles are separated, the finer material passing through and being further sifted by the fine sieve 12. The meal passing this fine sieve is collected in the space between this and the casing, and falls by means of the hollow standards supporting the grinding chamber into a hopper-shaped receptacle provided below, from which it is

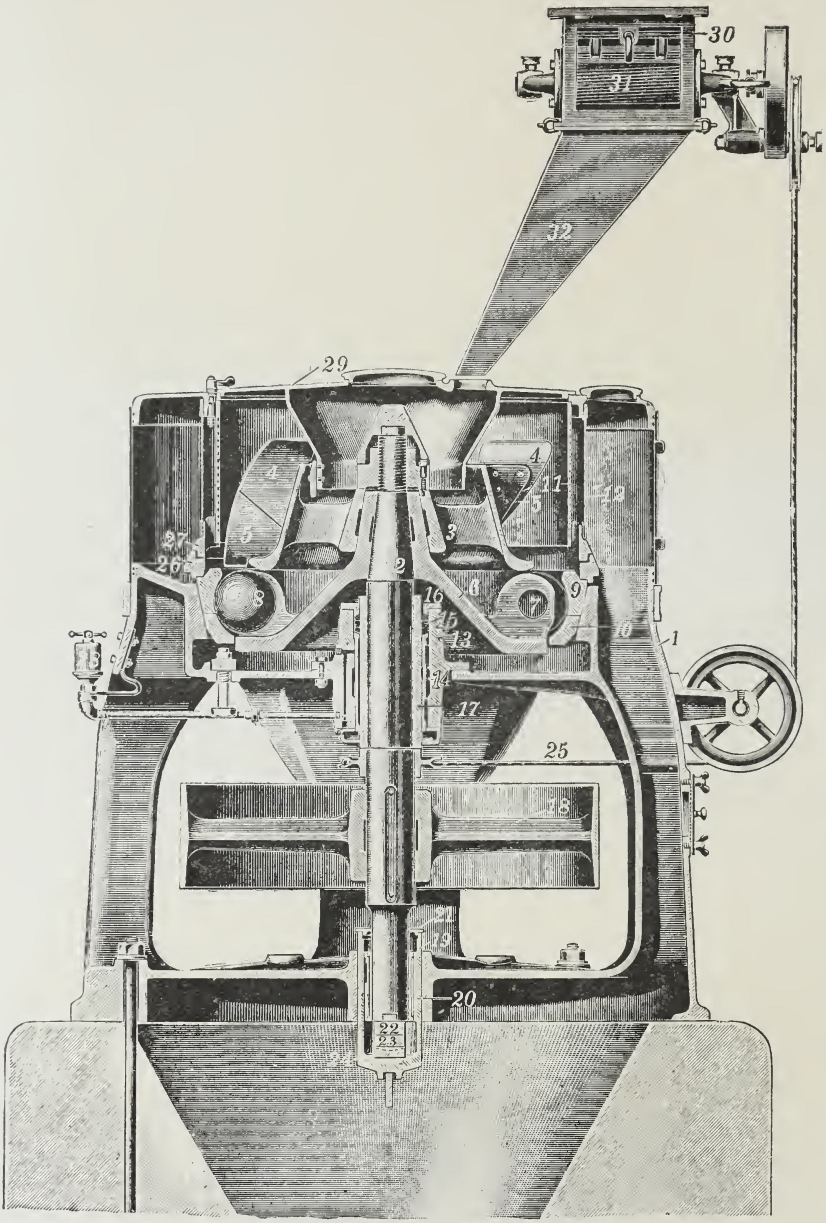


Fig. 52.—Section of Roulette Mill.

taken by a worm conveyor. The feed gear is driven from the vertical spindle by means of a gut or leather cord, and the neck bearing for the spindle is provided with a gland which prevents dust getting into the bearing.

The power required for driving is about 27 horse-power and the output, as with other mills, varies according to the fineness of the product and the hardness of the raw material. When fed with limestone of average hardness in pieces passing the $\frac{1}{2}$-inch ring its output is about 1 ton 10 cwt. per hour, ground to leave a residue of 12 per cent. on the 180 sieve. Grinding coal, its output is about 2 tons per hour reduced to a similar degree of fineness, and on rotary clinker 1 ton per hour of finished cement would be produced.

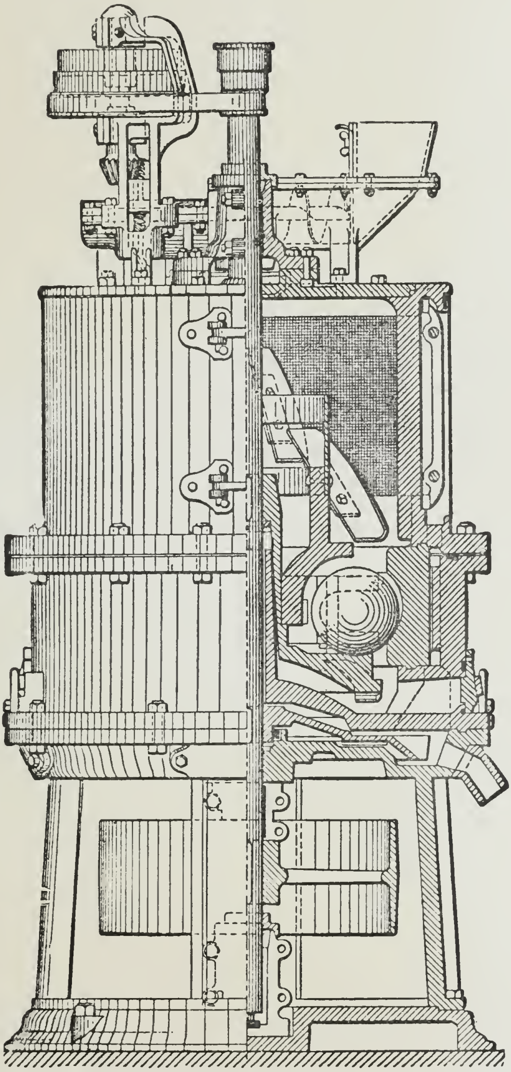


Fig. 53.—Section of Fuller Lehigh Mill.

The Fuller Mill is also a centrifugal ball-mill, and it is shown in section in Fig. 53. It is manufactured in two sizes, the grinding ring of the larger being 42 inches in diameter, and of the smaller 33 inches. In the mill of the 33-inch size the balls, of which there are four, weigh 1 cwt. each, and they are

driven round the grinding ring at a speed of 600 feet per minute. The arms that impel the balls are reversible and are secured to the vertical spindle. The material to be ground is fed into the centre of the mill, descends inside the cage to which the fan blades are secured, and is driven outward between the balls and the ring. The fine sieves are protected from undue wear by a protecting grid, and the ground material collected in the space between the sieve and casing is discharged by the chute beneath the grinding chamber. The power required for driving this mill is from 30 to 40 horse-power, and its output on coal has been found to be 2 tons 10 cwt. per hour, the product leaving not more than 2 to 3 per cent. on the 100-mesh sieve. Grinding raw materials of the Lehigh district, the output is from 4 tons to 4 tons 10 cwt. per hour, the product leaving a residue of 6 per cent. on the 100, and 15 per cent. on the 200 mesh sieve. Operating on rotary kiln clinker, its output is about 2 tons 10 cwt. per hour, the power consumed being about 40 horse-power. The feed for this mill used as a fine grinder should be in pieces no larger than will pass a $\frac{1}{2}$-inch ring.

The foregoing figures refer to the 42-inch mill. The larger size, when employed for fine grinding raw material, the feed being in pieces passing the $\frac{1}{2}$-inch ring, will give an output of 7 tons of meal, leaving a residue of 12 per cent. on the 180 sieve and consuming 67 horse-power.

It has been stated that this mill is suitable for coarse grinding, but the manufacturers inform the author that they only recommend it for fine grinding.

CHAPTER VII

TUBE-MILLS

The tube-mill is, in the majority of cases, used for finishing the product of mills of some other type, but in some forms it is employed for the production of grit. In form this machine is a drum, containing a certain charge of balls. In operation the material is fed into one end of the drum during rotation, and it is discharged at the other end in a continuous stream. The essential difference between the mills described in this chapter from those treated of in the foregoing, is that the interior of the mill is not formed into a series of steps longitudinal to the axis of rotation but is approximately smooth. Otherwise, in many respects, certain of the mills previously described resemble, in so far as product is concerned, some of the machines described in this chapter.

The mode of operation of the tube-mill has been described in some detail in the chapter dealing with wet tube-mills, and to this reference should be made. Other things being equal, the fineness of the product is conditioned by the length of the tube. Consequently, a short tube-mill will produce a grit containing a certain proportion of meal, and therefore comparable with the product of a ball-mill which is of necessity further treated by a fine grinding-mill or air separator. The pre-grit mill of Messrs Krupp is a machine of this type. In construction it is a wrought-iron cylinder, the length of which is about one and a half times its diameter. The ends are formed of cast steel, cast in one piece with the trunnions. The material is fed into the mill through the hollow trunnion at one end journalled in a bearing, and the product is discharged through the trunnion at the end which bears by means of a tyre on two rollers. The discharge trunnion is connected by means of a conical extension with a slotted steel cylinder which is enclosed in a dust casing; any large pieces

are in this way carried over the edge of the cylindrical screen, while the finer portions, falling through the holes, are led away by another chute. The tube is rotated by spur or bevel gearing. The material, fed into the mill by a shaking feed, may be in pieces up to the size of a walnut, and a mill 1,800 mm. in diameter and 4,000 mm. long will produce nearly 9 tons of grit from rotary clinker per hour. The Rotator of Messrs Polysius is a short tube-mill supported on rolls at both ends, as shown in Fig. 11, facing p. 28. It is employed for grinding dry material as well as wet, and produces a grit-like product to be subsequently treated in a mill of another type.

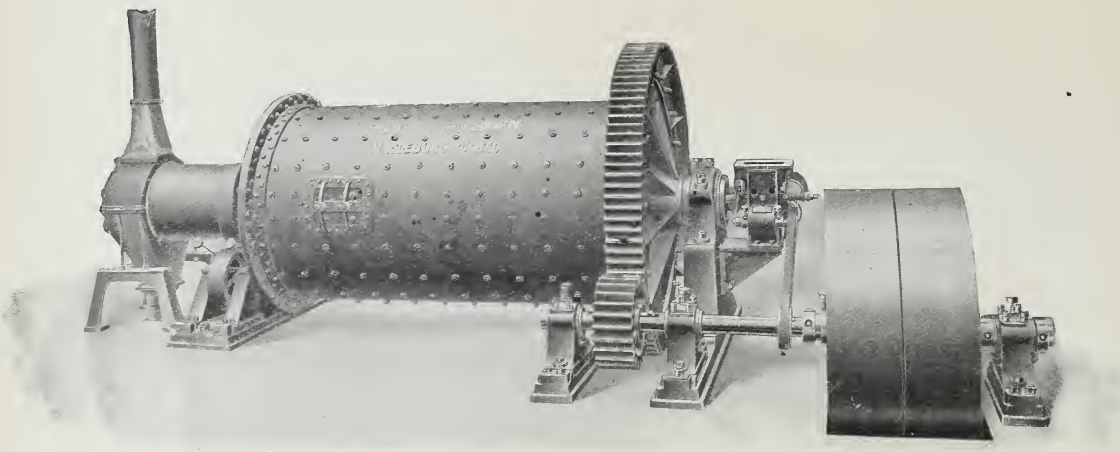


Fig. 54.—Krupp Pre-grit Mill.

When employed for coarse grinding the tube-mill is always loaded with steel balls and lined with iron plates. The product turned out by these mills varies with the size of the material fed in, with its quantity, and the length of the tube, which should be such, that a grit sufficiently fine, and in the required quantity, is obtained for feeding continuously the finishing-mill. The product of these mills can be treated in an air separator and meal of any degree of fineness may be thus obtained, the tailings from the separator being led back to the feed end of the mill.

The following particulars of a plant consisting of a short tube-mill and air separator may be given here:—The tube-

mill was of the peripheral discharge type and was 5 feet 2 inches in diameter, and 11 feet 8 inches in length, the air separator was 9 feet 2 inches in diameter. About 10 tons per hour of grit mixed with meal was discharged from the tube-mill when fed with rotary kiln clinker in pieces up to the size of hazel nuts, and from this the air separator furnished finished cement, leaving a residue of only 16 per cent. on the 180 by 180 sieve, at the rate of 4 tons 10 cwt. per hour. The power consumed by the whole plant, tube-mill, elevator, and separator, was 110 horse-power.

The tube-mill as a fine grinding machine is of greater length than those previously described, in which case its length is at least equal to thrice its diameter. As developed by Messrs Smidth it consists of a tube made, as a rule, by

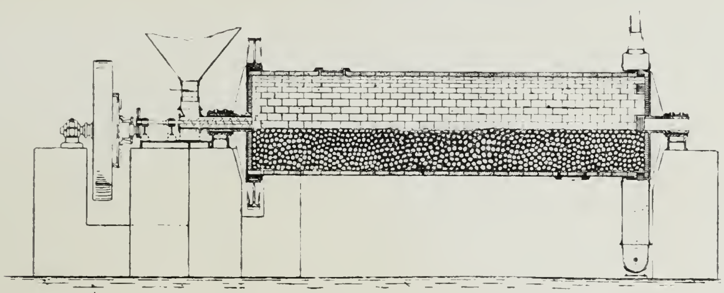


Fig. 55.—Section of Davidsen Tube-Mill.

bending a wrought-iron plate and welding the edges together, thus forming a cylinder. The ends, of steel, are cast in one piece with the trunnions, and are provided with webs. The material is fed through one of these hollow trunnions by a worm driven by a belt from a pulley on the countershaft to which the pinion engaging with the circular rack secured to the shell of the tube is also keyed. Round the periphery of the shell at the outlet end of the mill, a number of openings are arranged which are provided with grids. The material, as it passes through the mill, is ground by the percussive action of the falling balls, and is discharged through the openings at the opposite end, being collected by an annular dust casing surrounding them and led by means of a conveying and elevating plant to the storage

bins. A section of the latest type of mill manufactured by this firm is given in Fig. 55.

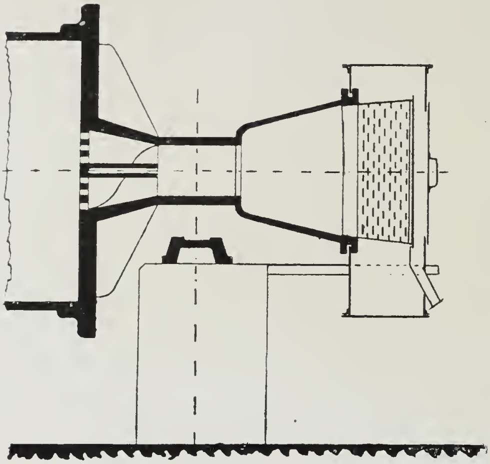


FIG. 56.—Discharge End of Krupp Tube-Mill.

The design of the Krupp tube-mill differs in certain respects from that developed from the patents of Davidsen, and chiefly in the design of the discharge, which is arranged at the centre instead of at the periphery of the mill.

The body of the tube is formed of a wrought-iron cylinder provided with webbed cast-steel end plates usually cast in one piece with the trunnions. The material is fed into the mill by means of a worm through one trunnion, and after traversing the length of the cylinder, it is discharged through the other trunnion, to which is secured a conical extension terminating in a cylinder of slotted plate. This cylindrical screen is surrounded by a dust casing so formed that the tailings, coarse pieces, and chips of flint are discharged by one chute while the fine material passing through the screen is delivered by another to the conveyor. To prevent the balls themselves leaving the mill, a perforated plate is secured inside the body of the mill by the outlet trunnion. The design of the discharge end is shown in Fig. 56. The advantage claimed for the central discharge is that it renders the mill less dusty in working, but when the dust casing is connected

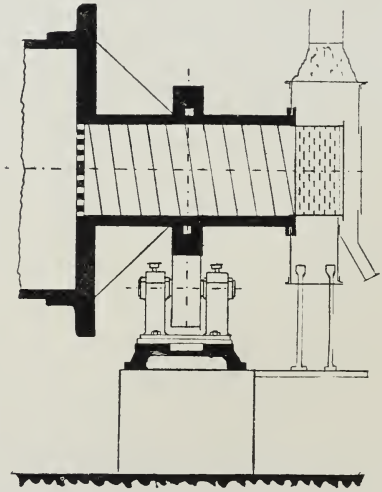


FIG. 57.—Discharge End of Krupp Steel Ball.

at the top to a pipe giving a good draught or to a dust collector, very little dust gets into the air of the mill chamber when a machine with peripheral discharge is employed.

Another design of the discharge end which has been extensively employed by Messrs Krupp is illustrated in Fig. 57. In this case the end plate is secured to a cylinder, the inside of which is provided with a spiral. A coarse grating is arranged inside the mill to prevent the balls passing out, and the material is led by the spiral on to the slotted or perforated screen, the chips of flint, &c., passing over the end; the fine material and the tailings being collected and separately discharged by a casing similar to that employed with the mill of the same manufacture previously described. With this form of discharge the mill is supported at the outlet end, not by a bearing, but by two friction rollers upon which the cylinder bears by means of a tyre secured to it. Most frequently in mills of this design steel balls are employed instead of flints.

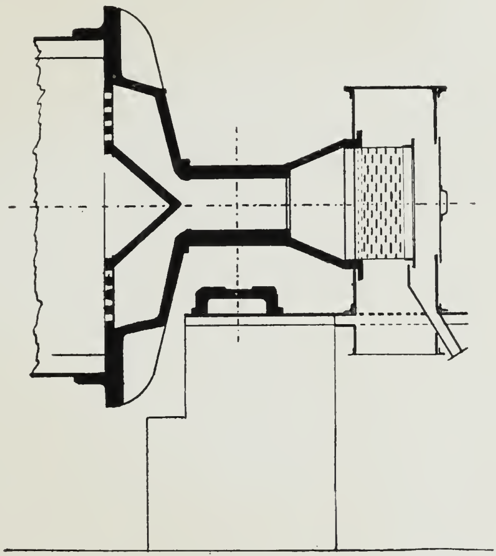


Fig. 58.—Discharge End of Polysius Tube-Mill.

The construction of the tube-mills manufactured by Messrs Newell differs in certain respects from those already described, in that the end plates are discs of mild steel and the cast-steel trunnions are bolted to them. The feed gear employed is also somewhat different. The grit is first delivered into a short paddle blade conveyor, from which it descends into the feed worm; the object of the paddle blade conveyor being to keep the material in a loose condition, thus preventing it packing the worm. In the larger sizes of tube-mill manufactured by this firm, a cast-iron ring or tyre is

secured to the shell midway between the trunnions. This tyre bears on two rollers, which are adjustable, and keep the weight of the mill from bearing unduly upon the bearings in which the trunnions revolve. In other respects, this mill resembles the Krupp tube-mill with hollow trunnions journalled in bearings.

In the Polysius tube-mill, the finished material is discharged through a grating of peculiar design, the result of which is to give to the mill the advantages of peripheral discharge, combined with those resulting from the adoption of the hollow trunnion and perforated screen. In Fig. 58 the design of the outlet end is shown. The end plate, which is dished, is cast in one piece with the trunnion, and the diaphragm at the end of the grinding chamber is provided with a number of rows of holes, the middle being in the form of a cone and unperforated. In operation, the fine material passes through the grating and the cone aids in leading the finished material to the trunnion through which it passes on to the cylindrical screen, the fine material being collected in the dust casing, while any chips of flint or nibs are discharged by another chute. In this mill, the trunnions as well as the first motion shaft are journalled in oil chamber bearings with ring lubrication.

The "Compound" mill of Messrs Löhnert is a ball-mill combined with a tube-mill in a common body. The ball-mill section is similar in design to that of the "Molitor" ball-tube-mill manufactured by the same firm. A section of the Compound mill is given in Fig. 59*a*.

The material to be ground is fed in pieces up to the size of a hazel nut, through the hollow trunnion situated at one end of the mill, and it passes through the section lined with step plates and containing a charge of steel balls to the outlet ports by means of which it passes to the coarse screen. The tailings from this screen are returned to the grinding drum by a number of return chutes arranged round the periphery of the mill about one-half the distance between the feed and discharge ends. The fine passes on to a casing of steel plate, arranged with the screen concentrically with the drum, and by means of chutes is delivered to the centre of the diaphragm

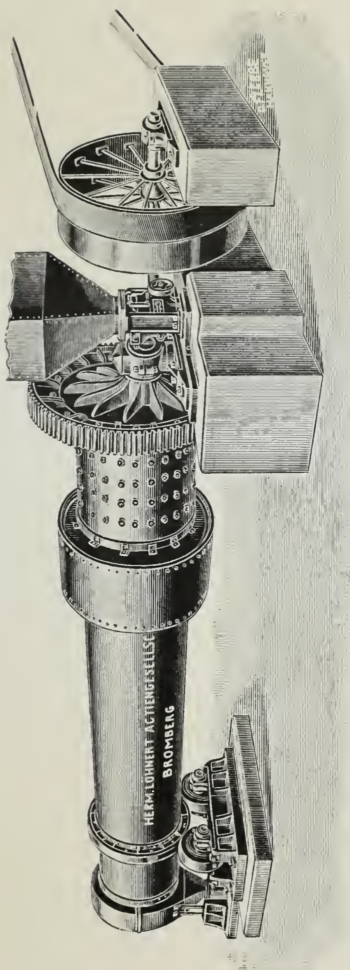


FIG. 59.—Löhnert's "Compound" Mill.

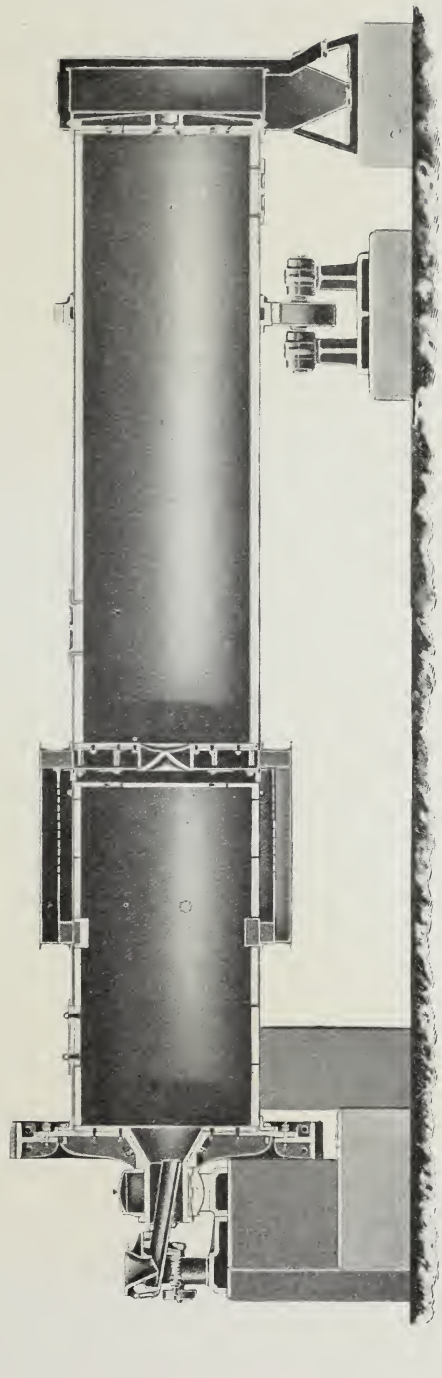


FIG. 59*a*.—Section of Löhnert's "Compound" Mill.

between the two sections of the mill. In its passage through this chamber, which is lined with plain steel plates, the grit is reduced to the fineness of meal, and it is discharged through the openings arranged round the end plate and is collected in a dust casing. The mill body near the discharge end is supported and revolves by means of a tyre on friction rollers. These mills are built in a number of sizes, and the largest has an output of 4 tons per hour of finished meal when working on material of a hardness similar to that of rotary clinker.

The mill just described is rotated by means of a circular rack secured to the end plate at the feed end, and this system is the most generally adopted for tube-mills. Occasionally the tube-mill is provided with bevel gear, in place of the spur gear usually employed, so as to permit of the mill being placed at right angles to the line shaft.

Reference has already been made to the Lenix drive in the chapter dealing with wet tube-mills.

When steel balls are employed in tube-mills the power consumed is considerably greater, as also is the output, as compared with a mill of similar dimensions in which flints are used. In weight the charge of steel balls is approximately double that of a charge of flints for a mill of the same size, and, naturally the strain upon the mill body and the pressure on the bearings is much increased. For this reason the ends have to be correspondingly stronger if the mill is journalled in plain bearings. Most frequently, however, the mill is supported at one or both ends on tyres. The system adopted by Messrs Krupp has already been described and illustrated. The steel-ball tube-mill (the Finitor) of Messrs Polysius is supported at the outlet end on rollers, while the inlet trunnion is journalled in a large ring oiled bearing. In other respects it resembles the same firm's tube-mill with flint-stone filling. Messrs Löhnert manufacture a type of mill which differs widely from the design already described. The feed end of the mill is provided with a hopper by means of which the material is introduced. At similar distances from either end rolling rings are secured, and the shell bears by means of these on two pairs of rollers journalled in oil-chamber bearings. At a certain distance

between the two rolling rings a split toothed ring is secured, and by means of this the mill is rotated.

This type of mill is illustrated in Fig. 60, and it is made

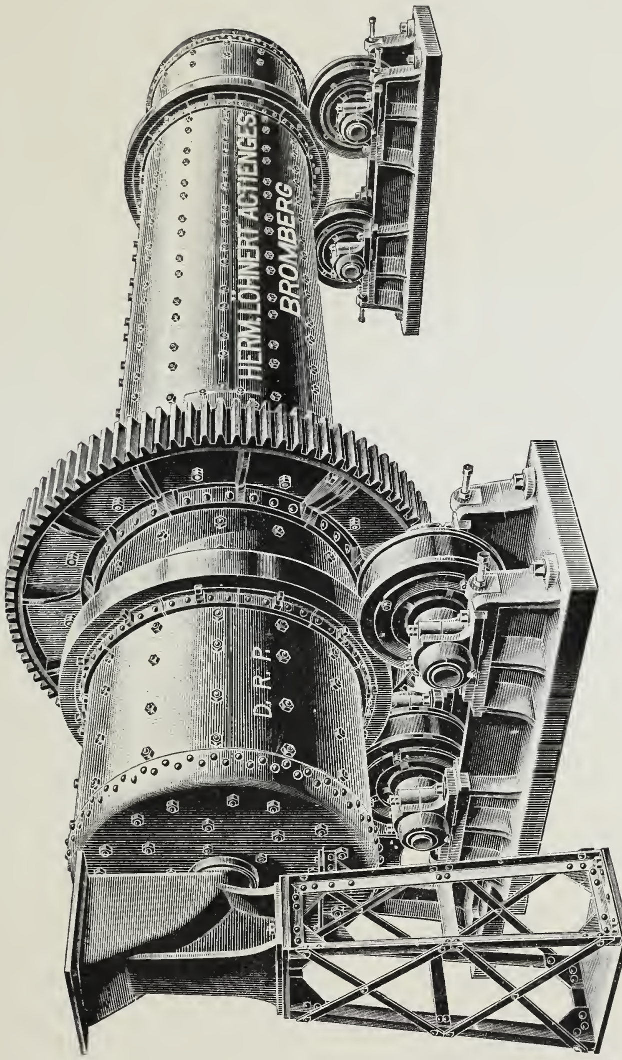


FIG. 60.—Tube-Mill with Roller Support.

in various sizes having grinding chambers up to 4 ft. 3 in. in diameter and 26 ft. long, and requiring a charge of 14 tons of steel balls.

In operation, tube-mills require to be kept up to their

load by the addition of flints or steel balls. The mills give their proper output at the required fineness when about half-filled with stones, and regular additions at definite intervals should be made. It is not sufficient to keep the level of the stones up to the centre line of the mill, as the grading and size of the pebbles have a considerable effect upon the fineness of the product. This, however, is only a point which comes into prominence when starting up or recharging a mill. When running it is only necessary to add flints from $2\frac{1}{2}$ to $3\frac{1}{2}$ in. on their greatest diameter. The quality of the stones sold for use in tube-mills varies considerably, and it is quite possible to obtain deliveries at about £1 per ton while others will be quoted up to £6. Although, doubtless, it is possible to get stones at a low rate which will actually wear a sufficient length of time to render their use profitable, it will be found as a general rule that the cheaper varieties split up in the mill, and not only is the consumption of flints excessive, but large quantities of chips will be found in the cement also. No satisfactory tests can be applied to flints so that records should be kept to indicate the wear of stones in relation to the output of the mill. It may be mentioned in passing that stones having a yellowish and semi-crystalline fracture possess good wearing qualities, while black flints are, as a rule, very poor in this respect.

CHAPTER VIII

CONVEYORS

The transportation of the raw materials and products of the different manufacturing processes presents a number of problems upon the satisfactory solution of which the success of the plant is largely dependent. The most primitive conveying and elevating appliances, which, it may be added, have all but disappeared from the cement trade, are the navvy barrow and pulley and basket. These have given place to the tipping wagon running on rails, and the power-driven hoist: instances of what may be called the "mass-transport" system. The two systems of conveying or elevating are sharply divided; the one in which the material is carried in relatively large units and long intervals, and the other in which it is conveyed in small units at frequent intervals approximating more or less closely to a continuous stream. Each is suited more especially to a particular class of work, the former for long distances and lumpy material, the latter for shorter distances and material in a finer state of division, while in certain fields they meet on debatable territory, the one or the other being used according to the tastes of the engineer.

Of the former class, the navvy barrow is an early example, and its successor is a barrow of larger capacity and supported on two wheels. The use of such barrows for the conveyance of any but occasional loads is to be deprecated, as the labour entailed is great, the man having to partially support its weight. The wagon running on rails is superior in every way to the barrow, as in this case, if pushed by manual power, only the friction has to be overcome and a man can easily propel a skip containing over half a ton of material. Unless the material is fed by gravity from bunkers or from an excavator of either the shovel or dredger type, the loading

of such wagons must be performed by manual labour. Wherever possible, and it is usually easy in the case of pits or quarries, the greater part of the material may be loaded into the skip by working the face in benches, the material falling into the wagon placed below. The unloading is performed by tipping the wagon.

Bricks coming from a press, especially if made by a plastic process, are somewhat tender, and they are therefore loaded into cars by hand and similarly unloaded. When they are passed through a tunnel drier, the car is provided with a number of stages and one layer of bricks is placed upon each, sufficient space being left between the individual bricks to permit of the free passage of the air. When dried, the bricks may be handled by means of barrows, tipping wagons, or mechanical conveyors.

So far, we have referred to the wagons as being propelled by manual labour, but horse, locomotive, or chain haulage is extensively employed. With a locomotive, the wagons are taken in trains. The locomotive is usually a steam engine, and lately, the use of fireless steam locomotives has been brought before the public notice. Such a system is by no means new: fireless locomotives having been used in coal mines where the use of a coal-fired engine would be the source of great danger. For long, they have been restricted to that field, but recently, in view of the fact that in all locomotive engines fuel economy is much lower than in a stationary steam plant, and that the largest item in the repair bill is on account of repairs to the fire-box and smoke tubes, they have been employed on several works. In place of the boiler a cylindrical tank partially filled with water is provided. At a convenient place a valve and connecting pipe is placed, by means of which connection with the steam main is made. The steam is blown into the drum until a pressure of about 160 to 200 lbs. per square inch is reached. With light loads and low gradients, the engine will work for eight hours; while with heavier loads, it will do from two to three hour's work. The insulation of the "boilers" is so good that during the night the loss in pressure does not exceed 30 lbs. In other respects, the engines are similar in con-

struction to the ordinary steam locomotive, while in operation, the fireman is dispensed with and there is no risk of explosion. These engines are made in a number of sizes, and will haul trains of up to 200 tons total weight.

Electric locomotives are also employed, to a certain extent, the current being collected by a bow from an overhead conductor. While useful for hauling trucks on private sidings, and on private roads generally, they have the disadvantage that they cannot go on to the companies' roads, and in certain cases the wagons have to be taken from the railway companies' sidings. The locomotive propelled by internal combustion engines has lately been extensively adopted. It is free from the objection against electric locomotives which have been just advanced, and like them, it possesses the advantage over steam-propelled engines that there are no stand-by losses due to keeping up steam. Shunting can be conveniently performed with electric capstans and one capstan can be made to serve several roads if guide rolls are placed in suitable positions. These capstans consist of a drum actuated through a friction clutch by an electric motor, the driving mechanism being enclosed in a watertight box, the clutch being thrown in by means of a projecting nob operated by foot pressure.

The small trucks or skips usually employed in pits and quarries are conveniently hauled by means of an endless chain, and when employed upon inclined ways, the weight of the descending trucks counterbalances that of those ascending, and the consumption of power is limited to that necessary to overcome the friction of the system and the effect of gravity upon the material raised. The head station is provided with a vertical shaft, to which a chain wheel is secured. This shaft is rotated through bevel gearing, by means of a countershaft provided with fast and loose pulleys. The chain passes round the chain wheel at the head station, and round a similar wheel in a station near the working face of the pit. This latter wheel rotates in sliding bearings, an arrangement of weights being used to maintain the necessary tension on the chain. The skips run on two parallel systems of rails, the one for the up, and the other for the down cars. The

coupling of the skips to the chain and their uncoupling is rendered automatic by the use of a simple fork secured to the bucket. Similar contrivances are in use, employing a wire cable for the haulage, and in certain cases this is laid below the cars, rollers being provided to prevent the cable coming into contact with the sleepers. The use of wire ropeways for the conveyance of raw materials, coal, half finished and finished products presents advantages under certain circumstances. For comparatively long distances, over steep gradients, and in rough country, in economy, it is unapproachable by any other system of transport. Over roadways, railways, and in cases where the cost of a right of way and the necessary land for a light railway would be excessive, it forms the cheapest means of conveying material. Even for short distances over blocks of buildings it is economical, and is frequently the only system of transport that can be adopted.

Ropeways are constructed on several systems, each of which is more suited to certain particular circumstances; they may be summarised as follows:—

1. The endless running rope system by frictional contact: suitable for lines carrying not more than 50 tons per hour, and gradients not exceeding 1 in 3; loads not exceeding 6 cwt., and spans not greater than 600 feet.

2. Endless running rope with carriers rigidly fixed to the rope: suitable for the steepest inclines and for sudden changes of level; the wear on the rope is greater with this system than with others.

3. Double fixed rope, acting as rails, with an endless hauling rope, the carriers going and returning by way of separate ropes. This system is suitable for greater quantities than 40 tons per hour, loads exceeding 6 cwt., gradients over 1 in 3, and spans exceeding 600 feet.

4. Single fixed rope and endless hauling rope for long spans, being cheaper than foregoing systems, and able to deal with loads up to 5 tons on any gradient. Quantities exceeding 400 tons per day of ten hours have been dealt with by this system.

5. Two fixed ropes and endless running rope. With this

system extremely long spans can be negotiated with loads up to 5 tons. On inclined ways where the loaded cars descend no power is required for driving, indeed in many cases a brake must be employed to absorb excessive power. Where the loaded cars ascend, the empties descending counterbalance the weight of the ascending cars and only the power required to overcome the effect of gravity on the load and the friction of the system has to be employed.

The endless running rope system is very much cheaper than the fixed rope system. As stated above, it cannot be employed for steep gradients unless the carriers are rigidly secured to the rope. With all endless systems, unless the speed at which the hauling rope is driven is not greater than 2 to $2\frac{1}{2}$ miles per hour, shunt rails must be provided at the loading and unloading stations. The means for connecting the carrier to the rope must be such, save for the exception referred to above, that they can be uncoupled and coupled automatically. However, it must be sufficiently rigid to reduce slip to a minimum. With the endless running rope system, as arranged by Messrs Bullivant, the bucket depends from a carrier consisting of two V sectioned stirrups which grip the rope and two grooved wheels upon which the carrier is supported when on the shunt rails (see Fig. 61). With the double fixed rope and endless running rope system, a clip is arranged either above or below the wheels which run on the fixed rope.

FIG. 61.—Bucket and Carrier (Endless Running Rope System).

The rope in the endless running rope system passes round a large grooved wheel from about 6 to 8 feet in diameter at the head station, and by means of this pulley the rope is driven. At the tail station it passes round a similar wheel which can be moved toward or away from the fixed wheel and by means of this arrangement the correct

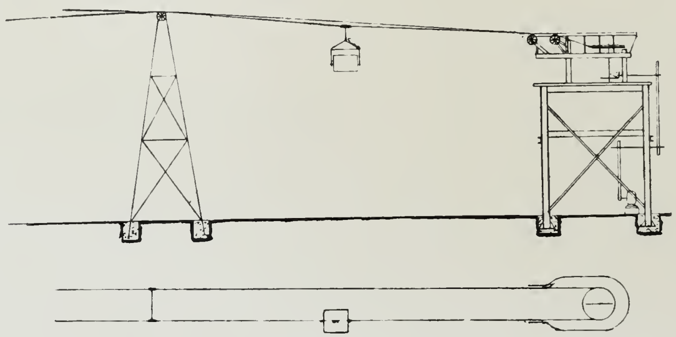


Fig. 62.—Diagram of Arrangement of Head Station, &c. (Endless Running Rope System).

tension on the rope is maintained. At intervals the rope is supported by grooved guide rollers supported on standards. The general arrangement is shown in Fig. 62.

The double fixed rope system is similar in many respects. The ropes are securely anchored at one end of the line and the other ends are secured to a tightening gear. The

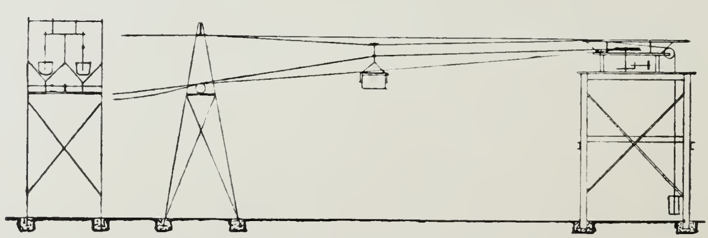


Fig. 63.—Illustrating Arrangement of Tail Station, &c. (Double Fixed Rope and Endless Hauling Rope System).

hauling rope is passed round a grooved pulley at the head station, while at the end station it is passed round a similar wheel provided with means for tightening the rope. The intermediate supports are provided with saddles for the fixed rope while guide wheels are provided for the hauling rope, as shown in Fig. 63.

Fig. 64.—Combination of Ropeway and Crane for Loading or Unloading Vessels in Deep Water.
(Messrs Bullivant & Co. Ltd.)

[*To face page* 127.

Another overhead way which has been adopted in certain works consists of a rail supported from hangers. Over the rail an electric conductor is arranged, and the trolleys supporting the buckets are provided with electric motors which take their current by means of bow from the conductor. The trolleys are sometimes provided with raising and lowering gear by means of which when they pass a particular station the buckets are lowered. For negotiating steep gradients an endless hauling rope system is provided to which the trolleys couple themselves automatically. Shunt rails for all these systems may be arranged at any desired point.

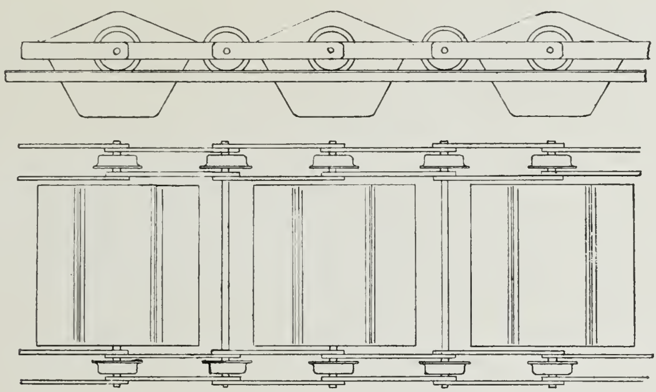


Fig. 65.—Bucket Conveyor.

Overhead tramways on a smaller scale are of considerable value for running slings of bags into carts or trucks or for loading boats. In this connection, a most interesting application of the ropeway is illustrated in the plate facing this page. It includes a staging upon which is mounted a crane operated from the shore station by the running rope which conveys the material to or from the boat.

The conveyors used for transporting material in small units or in a continuous stream are of the bucket, belt, plate, shaking, or worm types. Of these, the first four are particularly useful for transporting material in lump form, while the belt and shaker are also suited to the conveyance of material in the form of grit and powder, for which purpose the worm is also extensively employed.

The bucket conveyor, as its name implies, consists of a series of buckets connected together forming an endless chain. The form of this bucket, adopted by various manufacturers, differs in design. In the Hunt conveyor, it is of the form shown in Fig. 65, while in the Peck conveyor the buckets are so designed that they overlap. The connection between the buckets is susceptible of widely varying treatment, the

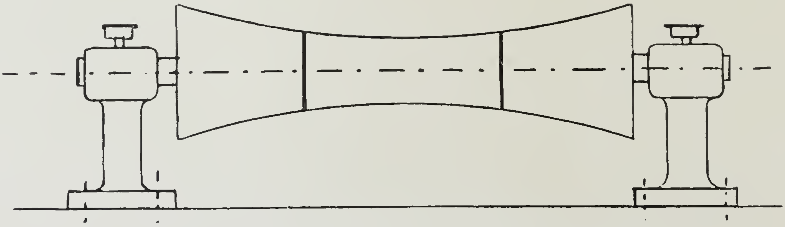


FIG. 66.—Curved Roll Support for conveying Belts.

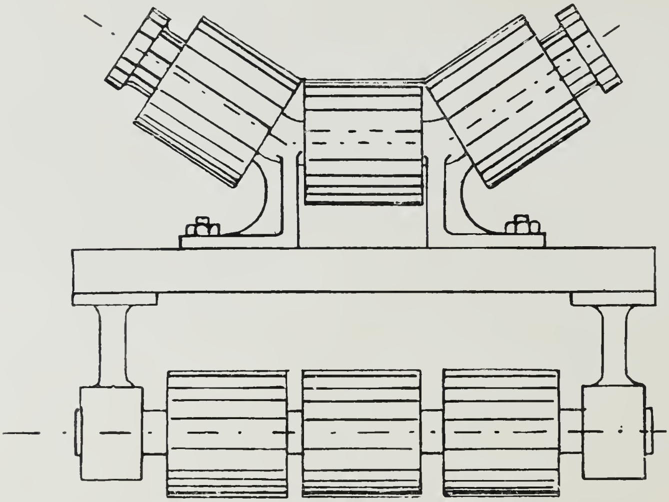


FIG. 67.—Usual Form of Supporting Rolls for Conveyor Belt.

chains being constructed to suit the idiosyncrasies of the designer. Two rails or skidder bars are provided, one on each side of the bucket, and upon these the flanged wheels taking the weight of the buckets run, similar rails being provided for the outward and the return sections of the chain. By means of a movable trip mechanism, the buckets may be made to tip automatically at any desired point, and the quantity of material carried can be automati-

cally weighed and registered by employing a weigher which may form an integral part of the plant.

Conveyors of this type are driven by means of a pair of sprockets with which the chains engage, the shaft to which the sprockets are attached being rotated by gearing from a countershaft, a motor, or other source of power.

The belt conveyor consists of an endless band of leather, or more usually of textile fabric, plain or rubber covered. This band passes round two rollers, one of which is held in fixed bearings and is driven by gearing, and the other is held

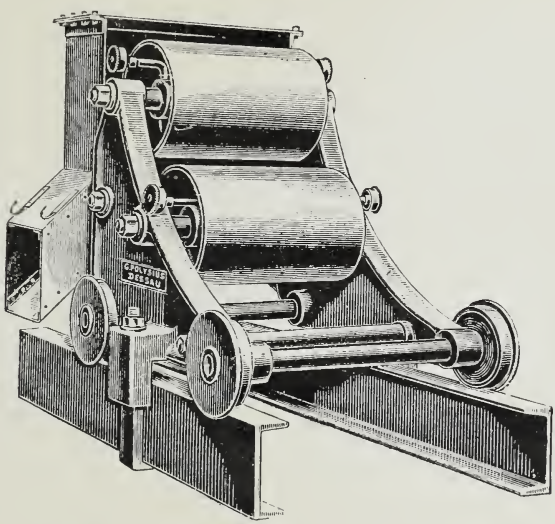


Fig. 68.—Throw-off Carriage for Belt Conveyor.

in sliding bearings by means of which the tension on the belt may be adjusted. At a number of points the belt is supported by rollers which prevent the belt sagging to an inordinate extent. These rollers are of different forms, depending upon whether a flat or curved belt is employed. In the former case, a single roller, cylindrical in form, is placed at the several points, while in the latter, three rollers, arranged as shown in Fig. 67, are employed, or a roller of the form shown in Fig. 66 may be used. The return rollers in all cases are plain cylinders. The strains upon a curved belt are naturally greater than on a flat, but, at the same

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time, for a given width of belt, the former has the greater capacity; more than double.

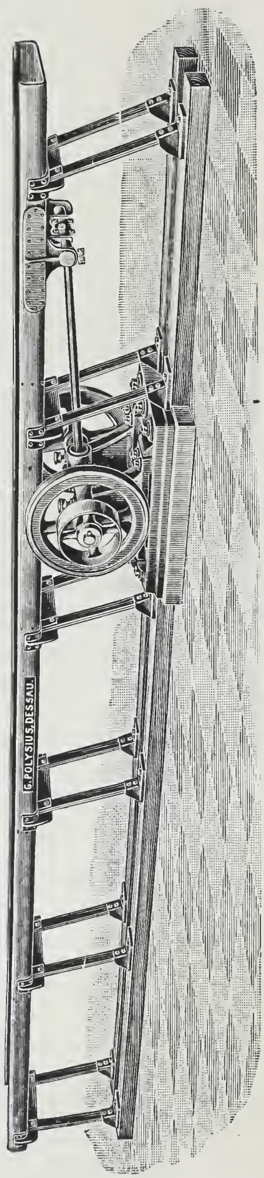

Fig. 69.—Shaking Conveyor.

Band conveyors are particularly well suited for conveying material long distances, but for lengths of less than 70 feet the worm conveyor is cheaper in first cost. The power required for driving is extremely small, as also is the wear and tear. The speed at which the belt is run is about 250 feet per minute. In order that the belt may deliver material at any required point, a movable carriage is provided. It consists of two rollers in combination with a distributing chute which enables the material to be delivered on either or both sides of the belt at the same time. The construction of this throw-off carriage is shown in Fig. 68. The loaded belt passes over the upper roller, then partly round it, and under the lower roller, proceeding thence in its original direction. The material is tipped off the belt in its passage over the upper roller, and falls by way of the chutes to the receptacles provided for it.

The plate conveyor is similar in principle to the band conveyor, the difference being that the moving member consists of a number of plates secured to side chains by means of which and sprockets the conveyor is driven. The advantage of a plate conveyor over the band is that it can deal with hot material without inconvenience, moreover, its substance is much less affected by the action of the material transported by it. These conveyors are frequently employed for handling clinker.

The scraper conveyor may be mentioned here. It consists of a channel into which the material to be transported is fed, and along which it is propelled by means of a number of plates or scrapers secured to a single or double strand chain.

The shaking conveyor is extensively used for handling dry non-sticky material in lump or powder form; it consists of a trough made of steel plate supported on a number of legs. These legs are usually formed of three strips of hickory secured by a bolt to a bracket riveted to the trough and to steps secured to the foundations. The trough is oscillated by means of an eccentric or crank at a high speed, the material being propelled forward with a jigging motion. The number of revolutions of the crankshaft is 250 per minute, and the stroke is about 2 inches.

The principle upon which this conveyor works is that, by the forward and slightly upward motion given to the trough, kinetic energy is imparted to the material contained in it which consequently moves forward. On its return stroke, the trough is pulled down slightly, and the friction between the material being conveyed and the trough is consequently decreased. The result is that the net effect of the reciprocation of the trough is the propulsion of the material. By arranging grids at intervals along the trough, and by providing removable covers for them, the conveyor may be made to deliver at any desired point. The power consumed by these conveyors is small, averaging $\frac{1}{2}$ horse-power per ton conveyed through 100 feet. The cost of upkeep is moderate, the legs being the only part that need frequent renewals. The bearings of the crankshaft also wear at a somewhat rapid rate, but the cost of their replacement is not considerable. The support for the driving gear should be strongly designed, and the conveyor must be secured to a rigid foundation.

The Marcus conveyor is an oscillating conveyor, but it differs considerably from the machine just described. Its stroke is much longer, while the number of reciprocations per minute are much fewer.

From the schematic diagram, Fig. 70, its mode of operation can be followed. A crank secured to the driving shaft, driven from the line shafting or a motor, of course, moves

with a constant angular velocity. It is connected by a link to a crank secured to another shaft and to which it imparts a varying angular velocity. The curves shown exhibit the velocity and acceleration from moment to moment, and put into words, the trough moves forward with increasing velocity to a certain maximum when it rapidly decreases to zero, rapidly increasing to a maximum on its return and then decreasing until its direction is changed. From these considerations it will be seen that this conveyor is free from the shocks present with the other type. In construction, the conveyor consists of a sheet-steel trough supported by means of flanged

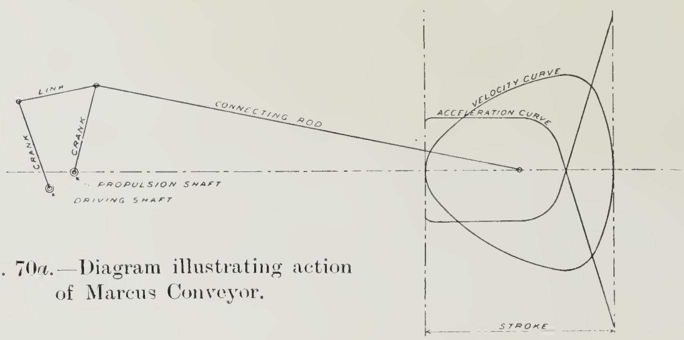

Fig. 70*a*.—Diagram illustrating action of Marcus Conveyor.

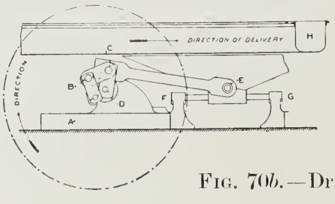

Fig. 70*b*.—Drive of Marcus Conveyor.

wheels on two parallel beams, such as channel bars. The driving mechanism of the type described is arranged at a convenient point beneath the trough, the propulsion crank being connected to a cross-head sliding on guides, the trough being rigidly connected to the cross-head. The speed of rotation of the driving shaft is between sixty-five and seventy-five revolutions per minute, the exact speed and length of stroke depending on the coefficient of friction between the trough and the material. In Fig. 71 an illustration from a photograph of the conveyor is given.

As examples of the capacity of these machines, the

following may be given. A conveyor with trough 50 metres long, 330 mm. broad, and 170 mm. deep, will convey 30 tons of clinker per hour at a speed of seventy-two revolutions per minute, and consuming 5 horse-power. A conveyor delivering 300 tons of coal per hour has been constructed, having a stroke of 12 inches and running at a speed of sixty-five revolutions per minute, consuming only 7 horse-power.

The worm or spiral conveyor is so well known that it may be dismissed with slight attention. It consists of a U-shaped trough in which a shaft provided with spiral blading revolves. The trough is usually formed of steel plate, as also is the blading, but under certain circumstances cast iron is

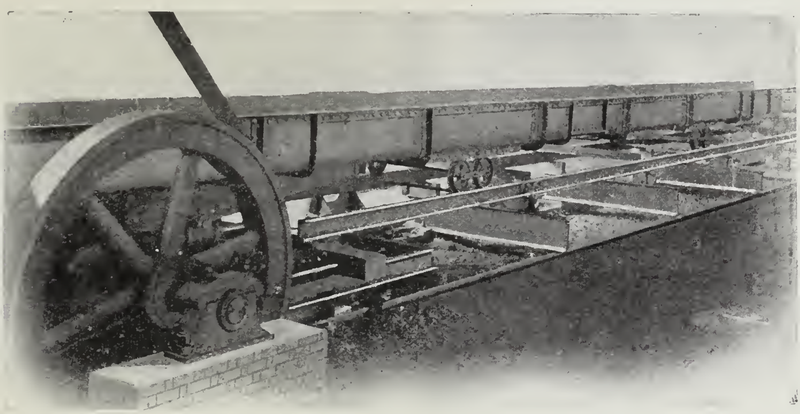

FIG. 71.—General View of Marcus Conveyor.

employed. The shaft itself is either of wrought iron or steel tubing or bar, and to it the blading is fixed by means of brackets. The shaft is made in sections, secured together by means of sleeves and gudgeons in the case of solid shafting, while with the tubular form a short length of rod is welded to one end of the tube, and the sections are connected by inserting the projecting pin of one section into the open end of the next, securing the two by means of a gudgeon, or the connection is effected by flanged couplings. At intervals, bearings are provided to support the worm, each of which is provided with a grease cup. Any number of discharge openings may be provided in the trough, and by means of slides any of

these may be closed at will. At the extreme end of the worm an opening should always be left so that any of the material carried forward by accident or oversight will be discharged. The maximum length of a worm conveyor recommended is about 160 feet.

The spiral conveyor or worm has the disadvantage that the bearings are partially covered by the material conveyed by them. This leads to considerable wear owing to the fine material passing into the bearings. What is essentially a spiral conveyor having all its bearings outside has recently been patented. The conveyor is in the form of a tube of

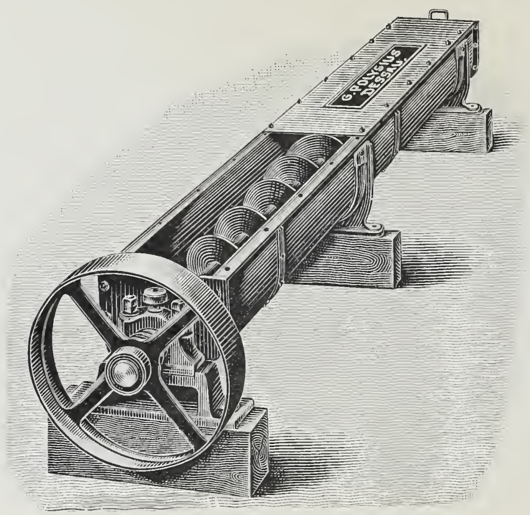

Fig. 72.—Worm Conveyor.

rectangular section and is provided with blades on the inner side of its walls. These blades are set obliquely to the axis of rotation, and they leave a small channel at each angle of the tube. When the tube is revolved the material is conveyed in either direction depending on the way the blades are set. The rotation is effected through a split pulley encircling the tube, and by suitable devices it may be arranged to discharge at any point. The design and operation of this form of conveyor can be understood from the diagram in Fig. 70.

A form of transporter which has met with considerable

popularity in the brick industry consists of a number of trays hanging by means of stirrups from a grooved wheel supported by a rail. The stirrups are connected by means of an endless chain or wire rope which is driven by means of a sprocket or grooved pulley. At curves or angles guide wheels are arranged for the hauling chain. With this type of conveyor briquettes may be taken from the press to the drier and stacked, while the dried bricks may be placed on the conveyor and taken to the kiln. An advantage possessed by this type of transporter is that it can convey the materials in any direction, changing from one level to another by means of inclines. It is most suitable for use with the ring kiln provided with a drier heated by the waste heat.

The means employed for raising materials are as various as those for transporting it in a horizontal direction and

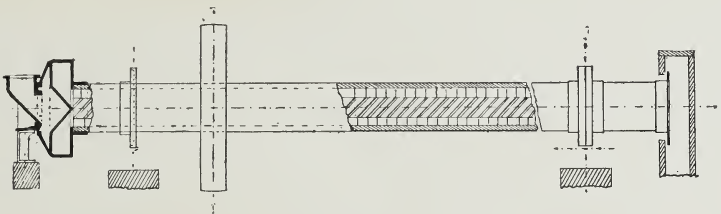

Fig. 73.—Tube Conveyor.

several appliances may be used for either purpose; tramways, wire ropeways, spiral, belt, and shaking conveyors, often being set at an angle to the horizon.

Cranes of most types are employed in cement works, notably for loading and unloading barges and other craft. When employed for unloading raw materials or coal they are usually provided with grabs in place of buckets or skips. These grabs dispense with the labour of filling, only a boy and the crane man being needed for their operation. In discharging they are also automatic. Grabs are of the single or double chain type. In the former, one chain performs the closing operation and the winding, while with the latter two chains or wire ropes are employed.

Hoists are frequently employed in cement works for various purposes, but now most usually they are employed

for raising raw materials and fuel to the loading platforms of shaft kilns. They are of the single or double type and as a rule are operated by means of a winch. In the first case, the skip is secured to one end of the rope, which, passing over a grooved wheel at the top of the staging, thence round the drum, is secured by its other end to a counterweight. With

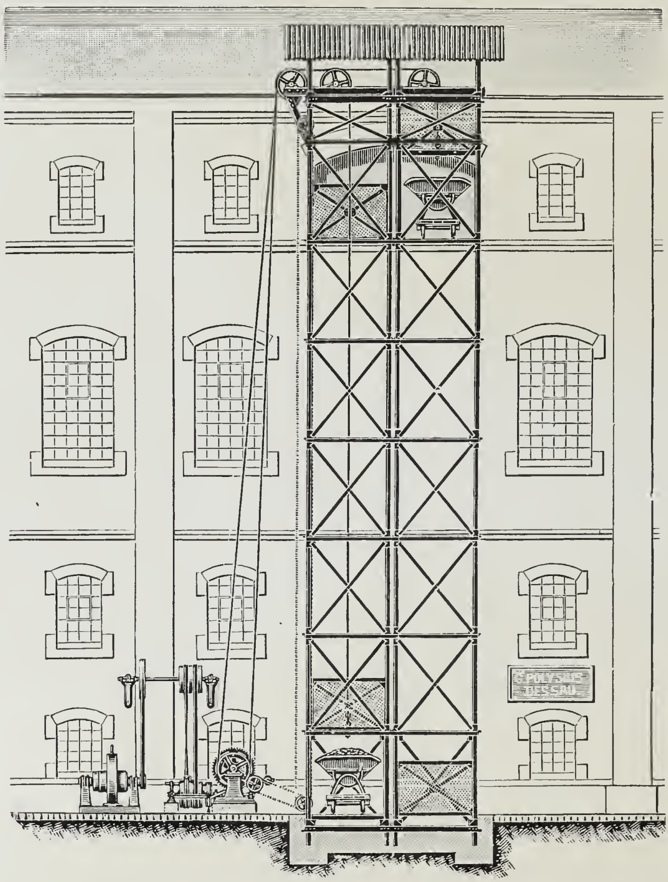

Fig. 74.—Double Hoist.

the double hoist, the rope, after passing round the pulley, is wound once or twice round the drum of the winch, and is then connected by way of the other pulley to the second cage: the length of rope being so arranged that when one cage is at the top the other is at the bottom of the lift.

The winch drum is usually driven by a worm and worm wheel from either a countershaft or direct by an electric

motor. When the latter system is adopted, the motor must be protected by a fuse or automatic cut-out properly set so as to interrupt the current if the motor is overloaded. The belt acts efficiently in preventing the motor being overloaded, as it either slips or breaks, thus preventing overwinding. Should the belt break from any cause, the cages remain stationary when a worm-driven drum is used. The cages are constructed with a steel framing, and should be provided with safety catches and guides. The double hoist is illustrated in Fig. 74.

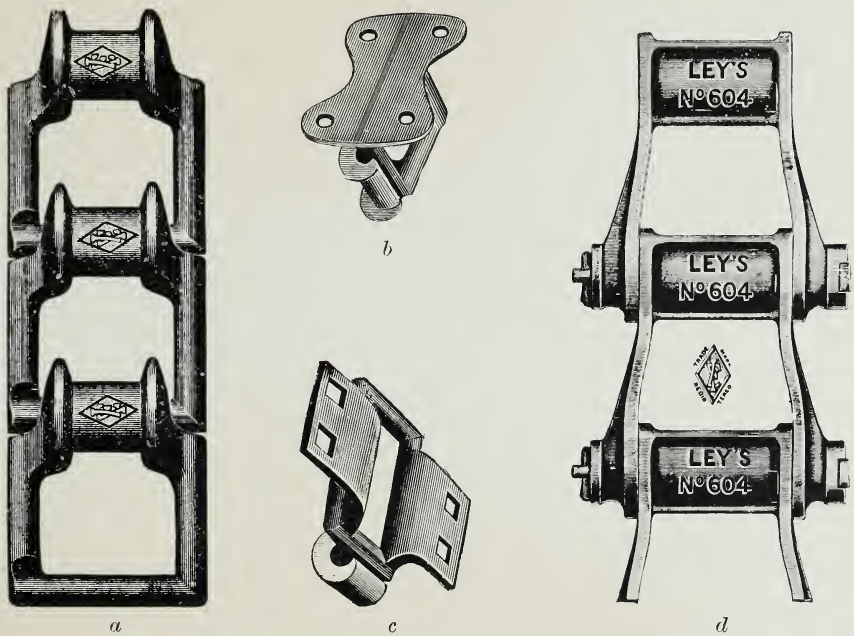

FIG. 75.—Link Belts and Attachment Links.

Elevators consisting of an endless chain or belt and provided with buckets are largely employed for handling material in the condition of powder, grit, or nuts. They may be arranged either for vertical or inclined lifts. The use of cotton or other textile belting is chiefly restricted to such elevators as are employed in dealing with non-gritty material, and even for such purposes the cable chain type is equally suitable.

The chains to which the buckets are secured are either plain cable chain, made of wrought iron, or of the link belt

description, in which case the links are mainly malleable cast iron. The latter form is extensively employed in this country, even for elevators dealing with meal or grit, but the advantages possessed by them are not apparent to the writer's mind. The cable chain elevator is quite capable of dealing with grit and meal, and also with material in relatively large pieces; the wear upon the chain is not great, and buckets can be removed and attached with great ease. In all cases with cable chains the buckets are secured to double strands, but with the link belt type single or double strands may be used.

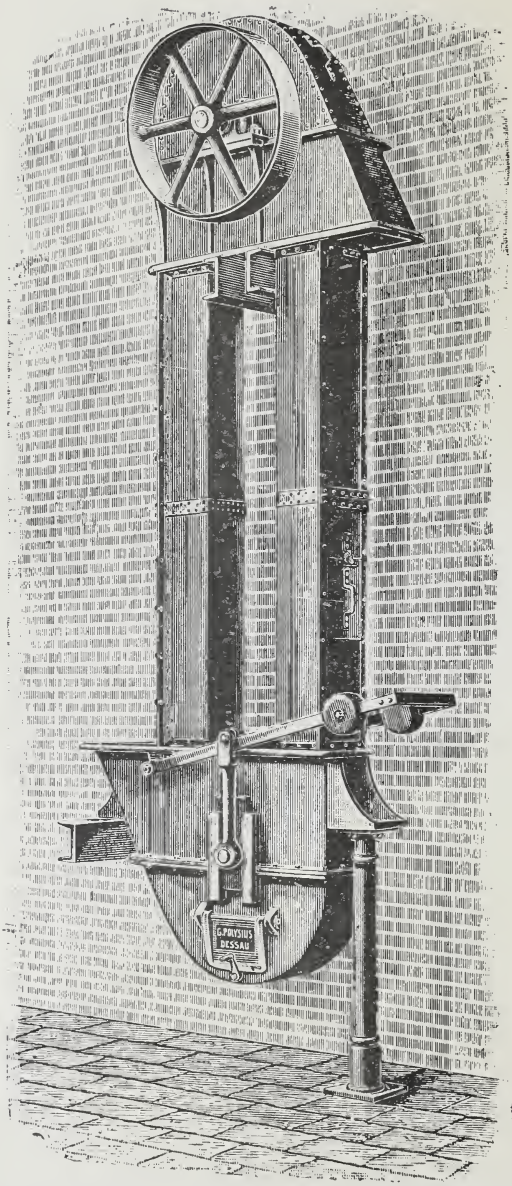

Fig. 76.—Elevator with Weighted Lever Tension.

In cases where the material to be elevated is in large lumps, or where a long inclined elevator is employed, the link belt is often installed. The early type, the Ewart chain, is illustrated at *a* in Fig. 75, and two special attachment links, *b* and *c*, are shown. The attachment *b* is employed as a rule when a single strand elevator is in use, while *c* is made

exclusively for the double strand type. The Ley bushed chain is illustrated at *d* in the same figure. With this type of chain a hardened steel bush only comes in contact with the sprocket, and the life of the chain itself is thus considerably lengthened, it being merely necessary to occasionally renew the bushes. There are numerous varieties of link belts, but there can be no doubt but that this latter form is the best suited for arduous working conditions.

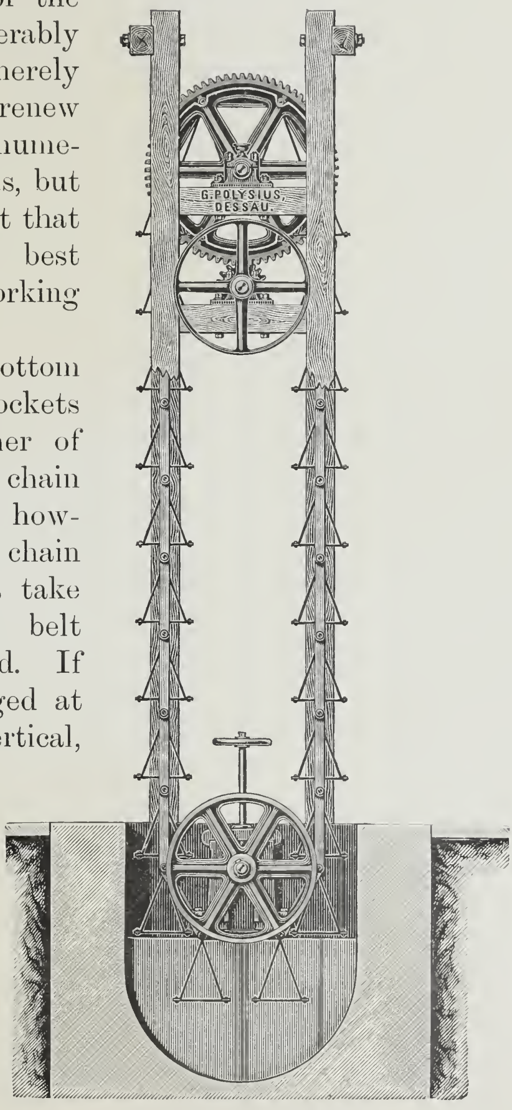

FIG. 77.—Brick Elevator.

At the top and the bottom ends of the elevators sprockets are provided when either of the two former types of chain are employed. When, however, the cable pattern chain is used, grooved wheels take their place, and with belt elevators drums are used. If the elevators are arranged at an angle to the vertical, skidder bars and guides or rollers are provided. The tension on the chain or belt is adjusted by journalling the bottom roller or sprocket in sliding bearings, and screws are provided for raising or lowering them. The use of weighted levers in place of these screws is to be recommended, as the bearings are then self-adjusting. An illustration of an elevator of this type is given in Fig. 76. The boot of this elevator is made in two pieces, and of cast iron. It is provided with

a door which renders possible the extraction of any material which may have caused an obstruction in the boot. The legs are of iron troughing in convenient lengths, the faces being formed of detachable plates secured to the angle irons which are riveted to the edge of the troughing. Sliding doors are provided at convenient intervals by means of which access may be had to the buckets, while the whole length of the elevator may be exposed by removing the face plates, which are secured simply with nuts. Elevators are driven either by means of a pulley secured to the drum spindle, or by means of spur wheels from a first motion shaft: the former system being only employed in elevators dealing with material in the form of grit or powder.

Buckets are now obtainable pressed from steel plate. Being in one piece, they are both light and strong, and are a considerable improvement on the older form made by bending and riveting. Cast steel and malleable cast-iron buckets are used in elevators dealing with lumpy hard material, as they will withstand more wear than either of the types previously mentioned.

Elevators used for raising bricks from one place to another are constructed, and in place of buckets, they are provided with a number of cages hanging from cross-bars secured at either end to the chains. These chains are frequently of the link-belt type, and run on sprockets, but in certain cases, built up chains with long links are employed and then specially formed wheels are employed. An elevator for this purpose is illustrated in Fig. 77.

CHAPTER IX

DUST COLLECTORS

Practically every individual portion of a cement plant is a generator of dust—which dust makes itself a nuisance in one or more ways. The most obvious indication of its objectionable character is the way it adheres to the various portions of the machinery and the buildings, necessitating the expenditure of money for its removal; that is, if any attempt is made to keep the works in a moderately clean condition. This, however, though the most obvious, is the least objectionable feature of dust.

Dust works its way into the bearings, adheres to gearing and causes considerable wear upon the moving parts of the machinery: for this reason its existence is most objectionable. Moreover, dust such as exists for the most part in a cement works indicates a waste of money, in that it represents the expenditure of so much power and work for the reduction of material to the state of powder.

In the case of clinker dust it represents the greatest waste, as the cement is the finished and the most valuable product of the manufacturing processes. At the same time it is the hardest, causing greater wear than the other forms of dust, and its alkaline properties have an injurious effect on the belts. For various reasons, then, the collection of dust is advantageous, the advantage being the greater when the dust can be utilised, as is the case when suitable plant is employed for collecting it and returning it to the main body of ground coal, raw material, or cement.

The means for separating dust from gases at a high temperature, which it is necessary to do when dealing with the hot air from clinker coolers, raw material driers, and kilns, are somewhat limited. For the latter the simple expansion chamber is the only means. Under the chapter dealing with

rotary kilns this question has been dealt with and the forms of expansion chamber, really capacious flues, have been described.

The brickwork cooler head with coal drier contiguous, enables the dust to be separated from the hot air. To this end the chamber is amply proportioned and is provided with an inclined floor, as often as not formed into a number of hoppers, doors being provided by means of which the dust can be extracted from the chamber without interruption of working. An arrangement of this type is illustrated in Fig. 126, p. 211.

When the steel plate moveable cooler head is employed, the air is drawn from it by means of sheet-iron pipes, and as a rule is taken directly to the coal drier, round the drum of which it circulates. The flues of the drier act as a dust collector, but their construction is usually such that the dust separating from the air is very difficult to extract, and that only by interrupting the operation of the drier. The interposition of a suitable expansion chamber would lead to the minimising of inconvenience arising from this source. By providing this chamber with a sloping floor and suitably disposed doors, the dust can be extracted at intervals, or the chamber may be made self-emptying by arranging a chute delivering it into a conveyor, which may be so arranged as to deposit it into the clinker conveyor. The bottom of this dust chamber can be made so as to empty the dust almost completely by forming it into a number of hopper-shaped cavities provided with chutes.

Similar arrangements are usually present for rendering the kiln flues efficient dust collectors and for automatically discharging the dust, thereby rendering possible a considerable saving in labour as compared with such as have to be periodically emptied by digging out the dust that has accumulated in them, an operation which is unpleasant from the workman's point of view. At the same time the quantity of material collected is gradually worked off when such self-discharging flues are employed, the dust being added to the raw mixture in a practically uniform proportion by means of a conveyor which conducts it to the kiln feed.

Expansion chambers may also be used in connection with mills for settling the dust formed in the pulverising operations. In most cases natural draught is made use of for causing the dust to pass into such chambers, and for carrying away the moisture usually present with the material. A fan, however, may be also employed when there is a difference of temperature between the atmosphere and the dust-laden air insufficient to cause a satisfactory current by means of a chimney.

The construction of the dust chamber need not be described, it being in most cases a simple box with or without baffle walls. Frequently the settling chamber is altogether omitted, the dust being led directly to the outside of the mill building.

The cyclone is one of the simplest dust collectors, and with moderately dry, dust-laden air it deals efficiently. Its construction is extremely simple, being merely a sheet-metal box in the form of an inverted cone provided at its wide end with a short cylindrical extension. The air from which dust is to be settled enters this box tangentially at its upper end; the dust being precipitated falls to the apex of the cone and the air passing out by way of a pipe situated in the centre of the circular plate forming the top. This form of dust collector has been used also in connection with driers for removing dust from the gases passing from them.

A very extensive class of dust settler is that in which the air is filtered through a textile fabric. This settler may be in the form of a box, one wall of which is formed by a sheet of flannel, or it may be arranged so as to form a series of cells. A modification of this type of dust collector consists of a box in which a sleeve or balloon is suspended, the dust-laden air being sucked through the fabric by means of a fan. The sleeve is shaken occasionally to dislodge the dust which has collected on it. When automatic means for cleaning the sleeves are provided, we have the dust collector of a type manufactured by several firms.

The principle upon which these installations operate is very simple. The air is drawn into a box with a hopper bottom and provided with a worm conveyor. From this chamber the air passes into a number of cylindrical sleeves

made of textile material, through which it passes leaving the dust adhering to the interior. A fan exhausts the filtered air, delivering it into the open. The sleeves are suspended from a lever which at intervals is rocked vigorously by means of a cam and spring. At the same time the connection between the cell and the fan is broken and air is drawn from the

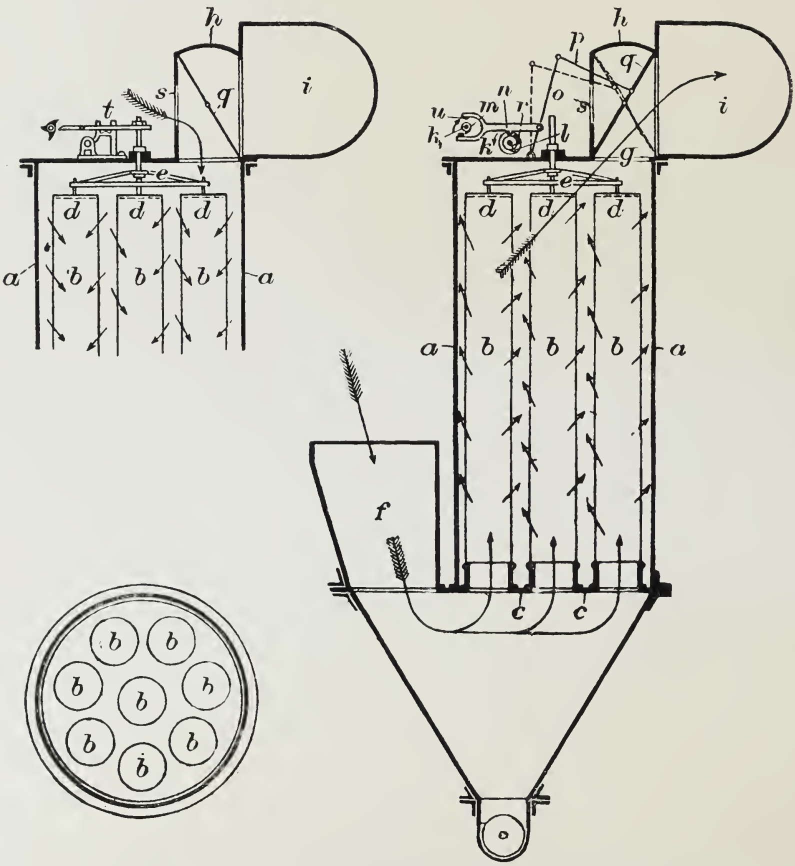

FIG. 78.—Diagram illustrating operation of Beth Dust Collector.

outside of the sleeve to the inside; in other words, the direction of the air current is reversed. The dust thus dislodged is collected by the spiral conveyor and returned to the main body of material.

From Fig. 78 the operation of the Beth dust collector may be easily followed. The dust-laden air passes in at *f* and thence into the sleeves *b*, the dust being deposited on

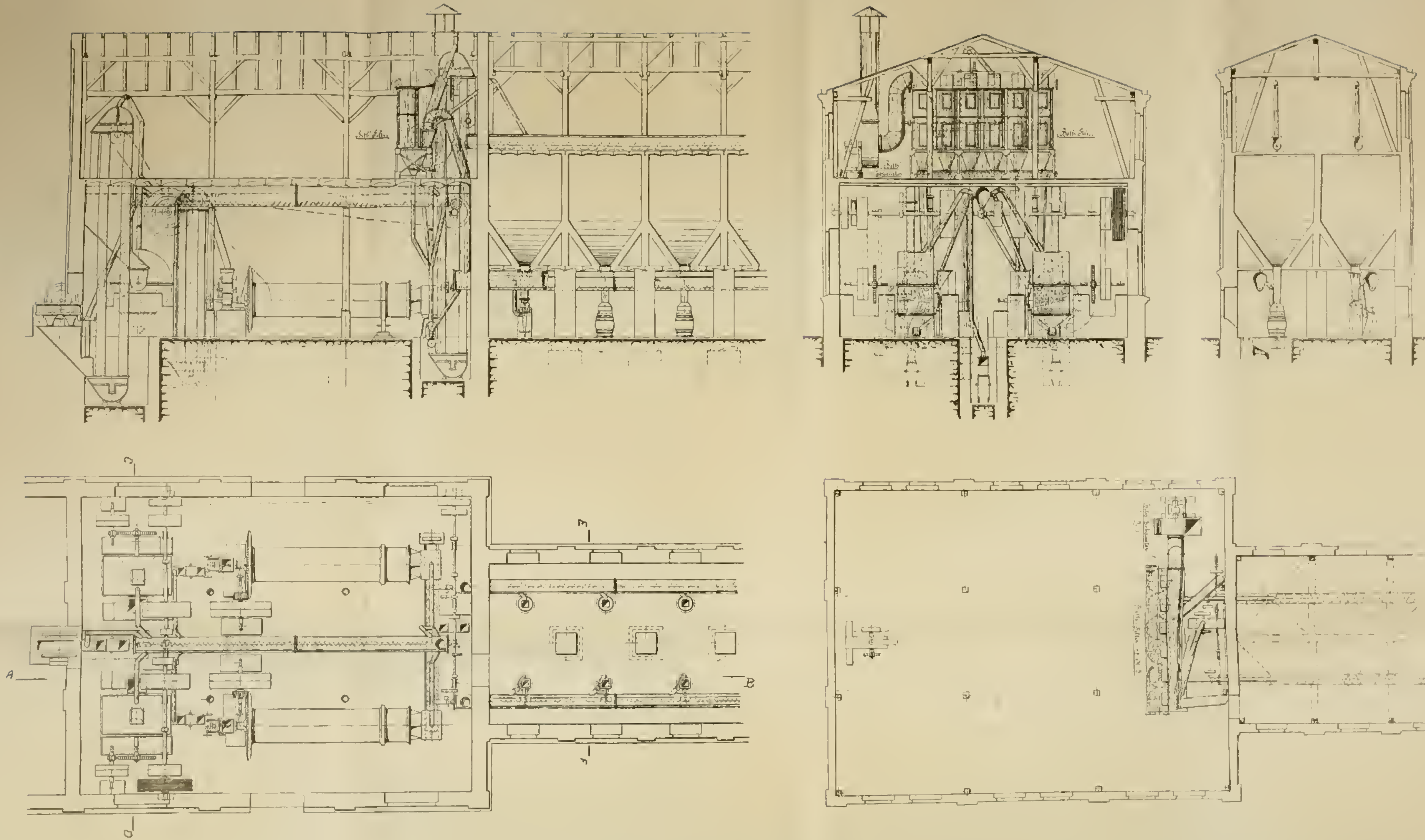

Fig. 79.—Complete Dust-Collecting Plant in connection with a Cement Mill and Warehouse

To face page 11

the fabric and the air passing through, and by way of *g* to the chamber *i*, connected with the fan. To the shaft *k* a cam is secured, which, operating the lever *n* by means of a pallet, raises it, bringing another pallet on the U-shaped end in contact with the cam *m* on the shaft k_1. This draws back the lever *n*, which, rocking the lever *o*, connected by the link *p* with the valve *q*, cuts off the connection between the cell and the fan by way of *i*, at the same time making connection with the outside air. Air rushes in through *s*, and passes through the sleeves *b* in the reverse direction and by way of the other cell to the fan. The lever *t* is drawn back at the same time as *n*, and comes in contact with the cam shown, which oscillates it, alternately drawing the sleeves up taut and letting them fall slack. The position of the valve is reversed by means of the pallet *u*.

In this form of dust collector the sleeves, while in the working position, hang slack, being merely distended by the air, and are only held in tension momentarily in the cleaning portion of the cycle.

These dust collectors are formed of pairs of cells having a number of sleeves in each: thus, while one is performing the filtering operation, the other is being cleaned. These cells are of circular or rectangular horizontal section (most frequently in the latter) and are constructed of iron or wood, the former only being employed where the risk of fire or damage by excessive moisture is great.

The general arrangement of a plant provided with this filter is shown in Fig. 79. As will be seen, the elevators, conveyors, the ball-mill casing, and the discharge end of the tube-mill are connected by means of pipes, to a collecting channel connected to the filter. This collecting channel is a trough of relatively large cross-section, and provided with a spiral conveyor. In this chamber a certain proportion of the dust settles, and by means of the conveyor is returned to the main body of material. The air from this collecting channel then passes to the filter, where the remainder of the dust is separated and also returned. Similar means are provided for collecting

the dust from the weighing machines in the silo, the general arrangement being shown in the above illustration.

A form of dust collector of American manufacture displays considerable ingenuity in design. The dust-laden air is blown by means of a fan into the drum *a* from which it passes to the cells arranged round it. The walls of these cells are made of cloth and the dust is deposited on the interior surface. The drum is slowly rotated by suitable gearing, and the various series of cells are successively inverted over the trough in which is a spiral conveyor. When in this position, air is drawn in through the walls of

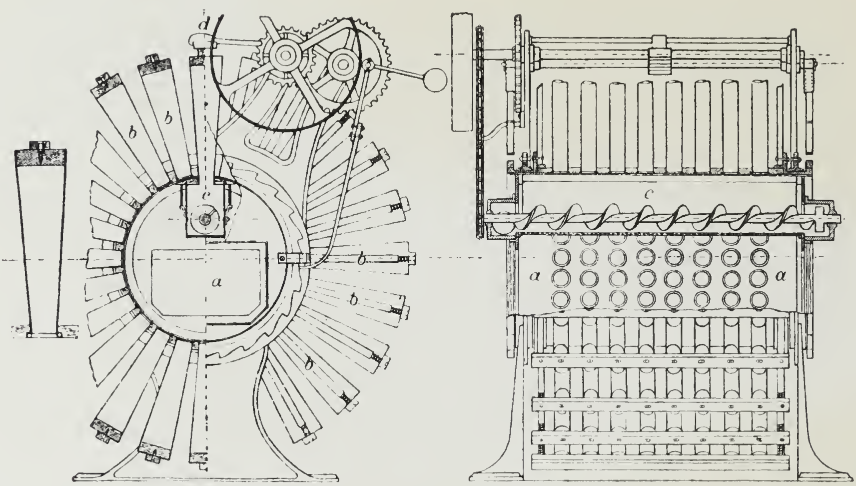

FIG. 80.—Perfection Dust Collector.

the cells by means of the fan, a pipe connecting the trough with its intake; at the same time a hammer *d* strikes the batten to which the outer end of the series of cells are secured and the adhering dust is dislodged, the conveyor returning it to the main body of the ground material or to a sack. The machine is illustrated in Fig. 80.

While dealing with dust in a dry form, collectors in which textile fabrics are used as a filtering medium, or spiral conveyors are present, prove generally satisfactory. When dealing with dust and a considerable amount of water vapour, especially if the material is inclined to set, they do not always work properly, the dust forming a pasty mass with

the condensed water. Whatever care is taken to dry materials there is usually a certain amount of moisture in the air drawn from the mills; this is particularly the case with coal, and the difficulty is even greater when materials which have been intentionally moistened are ground. Some means of adding water to clinker from a rotary kiln is often necessary, and thus the separation of the cement dust presents some difficulty. A part of this water passes through the mill as vapour, and to prevent its condensation the speed of the air current must be high and loss of heat must be avoided.

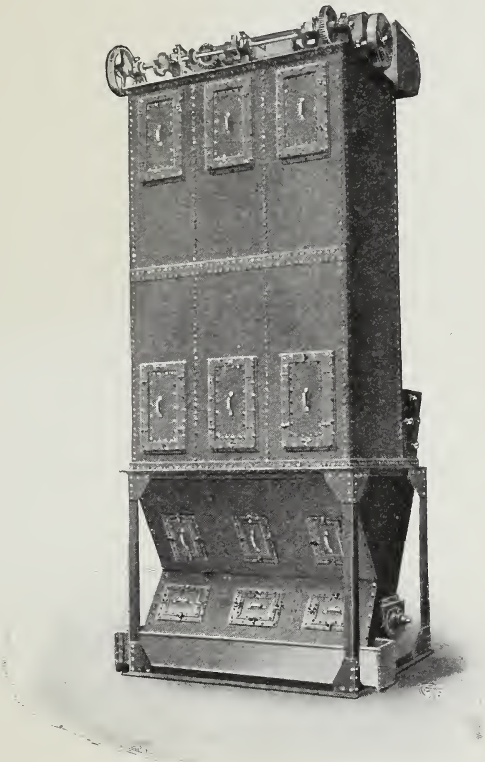

FIG. 81.—Dust Collector for Treatment of Moist Gases.

In cases where the quantity of moisture contained in the dust-laden air is excessive, a modified form of the Beth filter may be employed. It is so designed that the water condensing on the interior of the casing cannot find its way into the worm, a false bottom being provided which serves to collect the condensation, and lead it to a trough. The casing in this instance is made of steel plate instead of timber, on account of the liability of the latter to warp and swell in the presence of moisture. A dust collector of this type is illustrated in Fig. 81, and an installation of one in connection with a rotary drier for raw materials is shown in Fig. 82. This illustrates the actual plant employed at an English cement

works, where a "cyclone" has been replaced by a Beth filter.

Air from the simpler forms of dust collector may still contain a small proportion of solid matter in suspension. In most cases this is a matter of no importance, but in some a further means of purification may be required. In this event the air is passed through a chamber in which it is treated by a number of jets or sprays of water. This chamber may be in the form of a cylinder or rectangular box provided with a number of sprays or jets of the type known as sprinklers, such as are used for cooling condenser water or in the form of fire extinguishers. These jets emit the water in a fine state of division, thus bringing the dust-laden gases into intimate contact with the water.

The adoption of this device with dust filters is not necessary, and, when used in other cases, some means for creating the necessary draught must be employed.

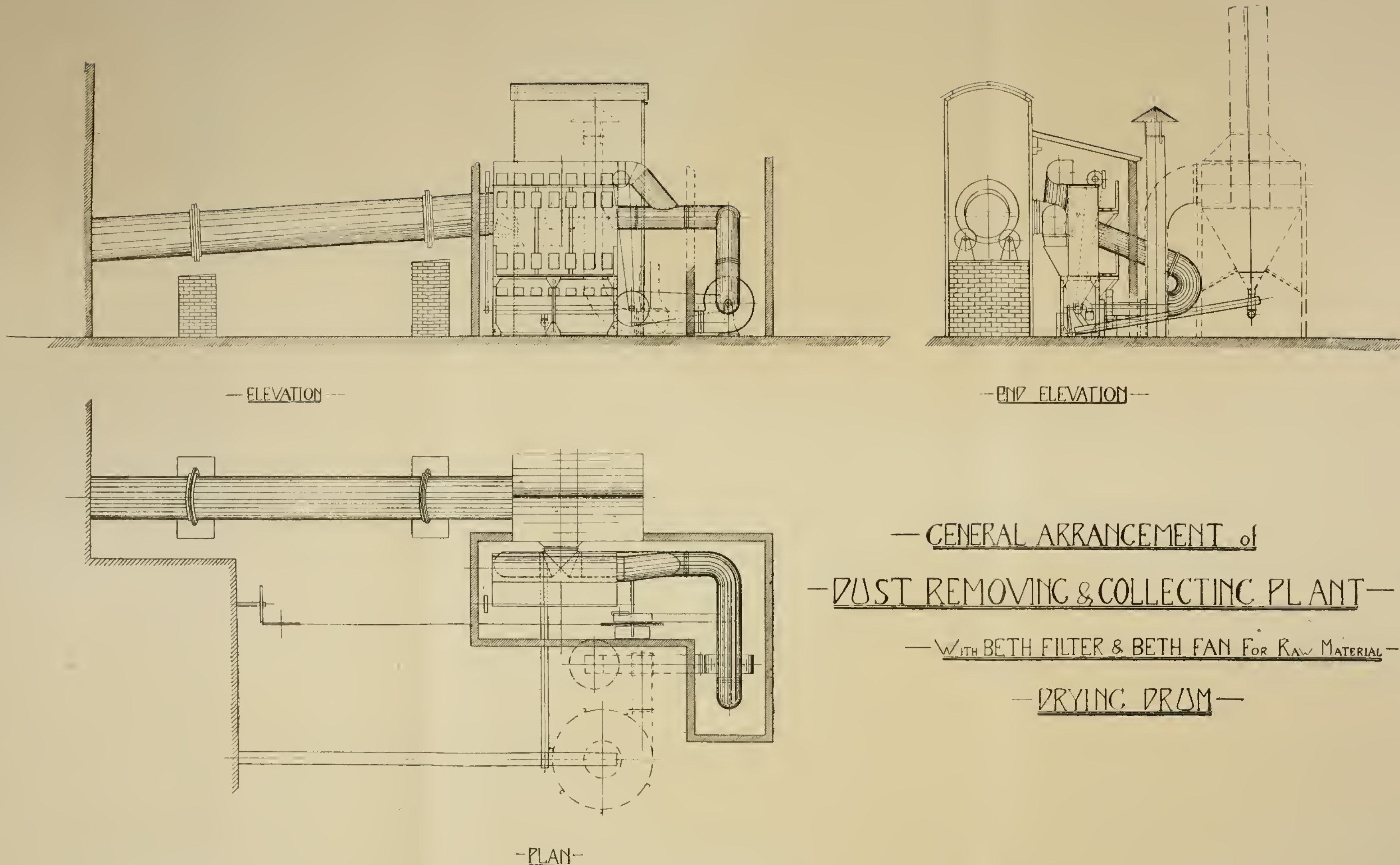

Fig. 82.

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CHAPTER X

WEIGHING MACHINES

In all manufacturing processes a greater amount of attention is now paid to details. Greater precision is evident in all departments, one result being indicated by increased uniformity in the quality of the products, and another in the manufacturing economy.

A means leading to both these results is the employment of measuring appliances in greater number and of greater accuracy. Although accurate measuring may not lead directly to a reduction of fuel consumption, for example, and therefore the cost of such measuring plant may appear at first sight to be unproductive, in operation such a desirable result must ensue, as it will enable the manager to select the more efficient burners from the number in his employment, and at the same time to observe any defects in the plant which may cause a falling off in its efficiency, when the consumption of fuel is compared with the output of the kiln. This necessitates the weighing of the clinker, which will also show whether the output is kept up to the highest point. Similar considerations apply to mills.

The use of weighers for all material delivered to the works and for the finished product are, of course, necessities and have long been recognised as such. While at the present time the modern manufacturer regards the employment of weighing and measuring machines placed at various points as equally indispensable.

The steelyard weighing machine needs no description here as its construction and operation are familiar to every one. In the form of the platform weigher, machines without loose weights are the most convenient. When cars or barrows of material are weighed, double steelyards are extremely useful, as upon one of them the poise can be secured in such

a position as to counterbalance the weight of the truck. The machine can be made to indicate the weight on a quadrant at a slight extra cost, and machines can be had which will record and total the weighings by printing both the total and individual weighings on a ticket or tape. The use of weighers of this type renders incorrect tallies an impossibility except by deliberate fraud, which is after all to be more carefully guarded against than is forgetfulness on the part of the tallyman. To overcome both of these potentialities the use of automatic weighers is the most practicable means.

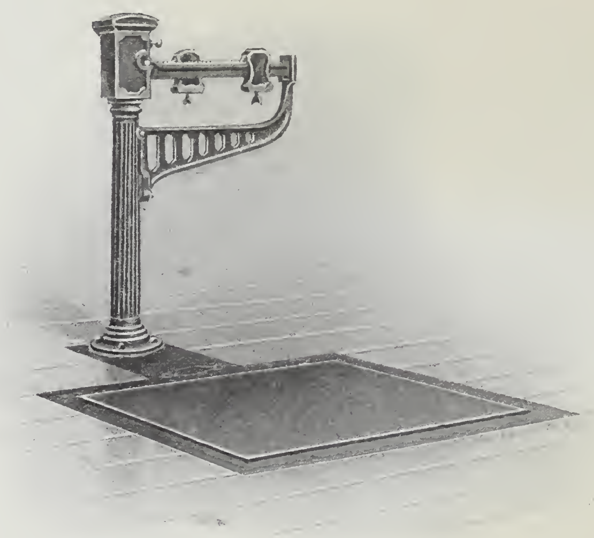

Fig. 83.—Platform Weighing Machine.

A hopper is in certain instances provided in place of the platform; in such cases the material is fed into the hopper by means of a shovel or by a conveyor or other device until the requisite load is obtained, when a door in the bottom of the hopper operated by a lever is opened and the contents discharged. While the platform weigher is more suitable for positions where the material is brought in barrows or trams from some distance, the hopper weigher is in advance of it where the storage of material is close at hand: so that the hopper can be filled by means of a shovel or by a con-

veyor. The hopper may be employed in conjunction with a machine indicating on a dial or scale or with the plain steelyard which may be fitted with printing and totalising attachments.

The use of a weighing machine in loading and unloading boats by means of a crane is often of considerable value,

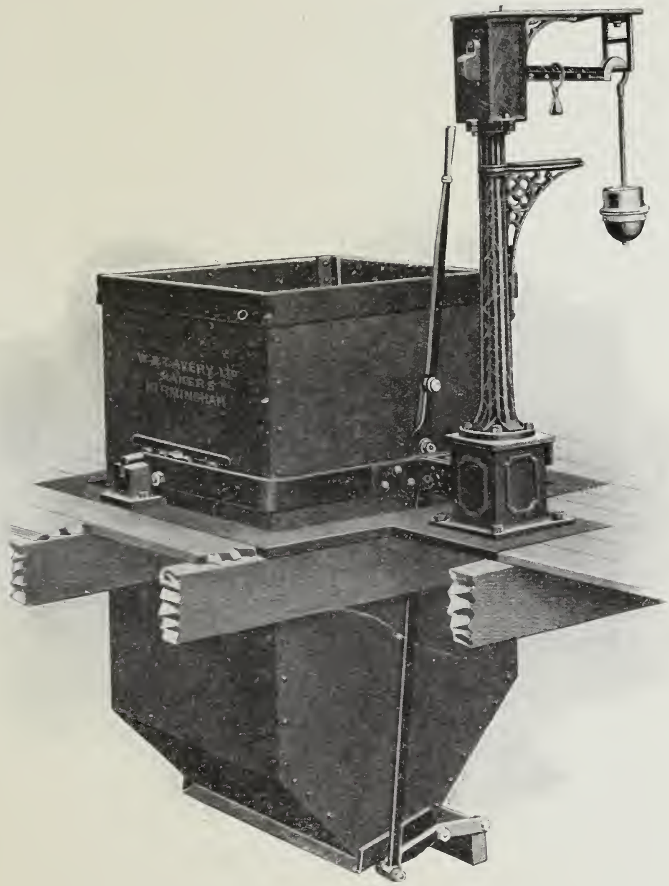

Fig. 84.—Hopper Weighing Machine.

enabling the weight of a cargo, as calculated from the draught, to be checked.

For this purpose two types of weigher which are hung from the crane chain are manufactured. In one of these the weight of the load is indicated on a dial, and only requires to be read off, while another type is a suspended steelyard

weighing machine, the sliding poises of which have to be operated by an attendant. Of the two types, the former is probably more convenient for most purposes, but the

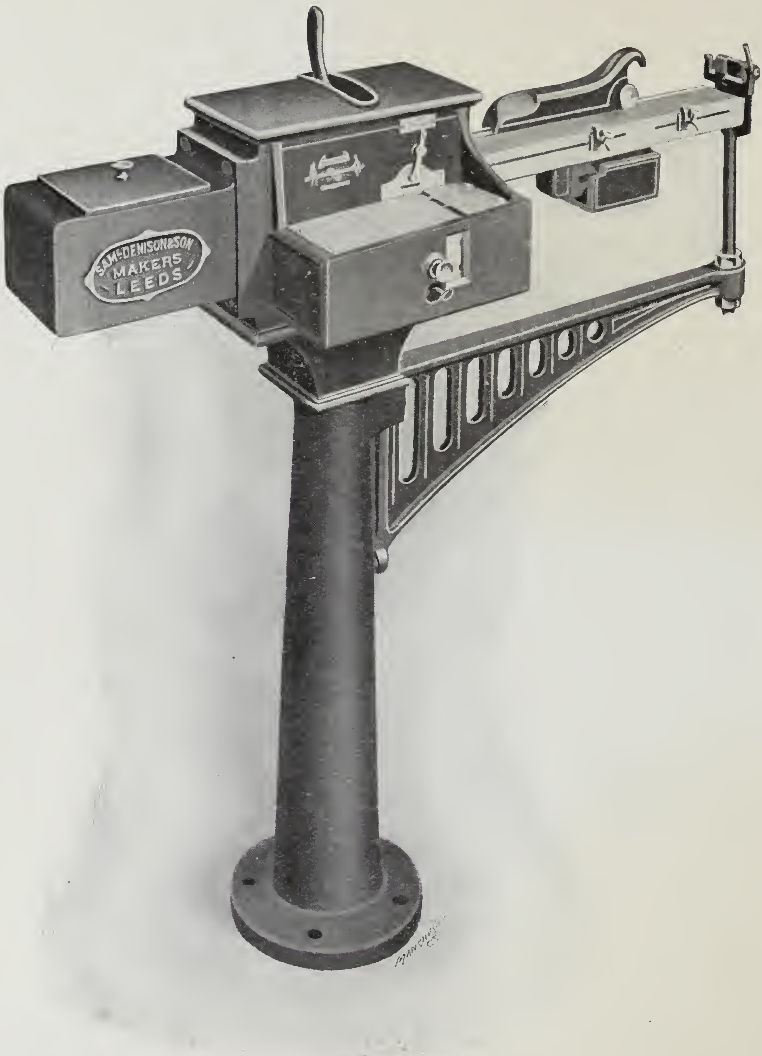

Fig. 85.—Printing Attachment for Weighing Machines.

choice must be left to the user, who will of course be more conversant with his own requirements.

Automatic weighers may be divided into three classes: those which, by means of a feed gear, deliver the material

into a receptacle which then discharges, the weighed quantity passing to a conveyor, elevator, bin, or sack; those which weigh material in sacks; and those which weigh material as it is passing over a conveyor.

The first class or automatic hopper weigher is constructed in several different forms. In one type the hopper is made in one of a number of forms chosen for its suitability in connection with the material to be weighed. When it is of a clogging nature, such as material in powdered form, the hopper is often in the form of a cylinder. This hopper is suspended from one arm of an equal armed beam, the weights being placed on a platform suspended from the other. The material is fed into the hopper from a chute provided with valves. As the beam sinks, one valve closes and the other allows only a small stream to dribble into the hopper, which, continuing to descend, cuts off the flow when the requisite weight is contained in the hopper. Immediately after this point is reached, the door at the bottom is opened by means of a system of levers and the contents are discharged. When the discharge is completed, the door closes and the hopper rises, the cycle of operations being then repeated. The machine is illustrated in Fig. 86.

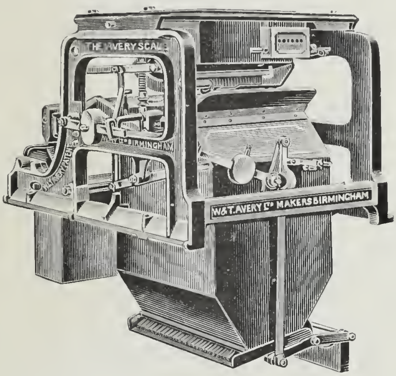

FIG. 86.—Avery's Automatic Hopper Weigher.

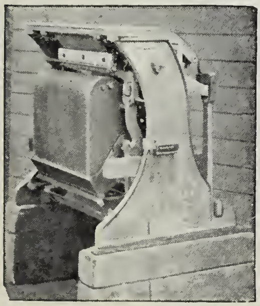

FIG. 87.—"Nomis" Weigher.

The "Nomis" automatic beam scale is a weigher which has proved itself to be thoroughly reliable, even when working under the trying circumstances prevailing in a cement works and when operating on such clogging material as cement. The hopper is supported on one arm of an equal armed beam, the weights being supported on a carriage sus-

pended from the other arm. The material to be weighed drops in from a chute provided with a valve. As the weigher fills and the weights rise, a pawl secured to the weight carriage comes in contact with a crank connected with the feed valve. The crank is thus raised until over the

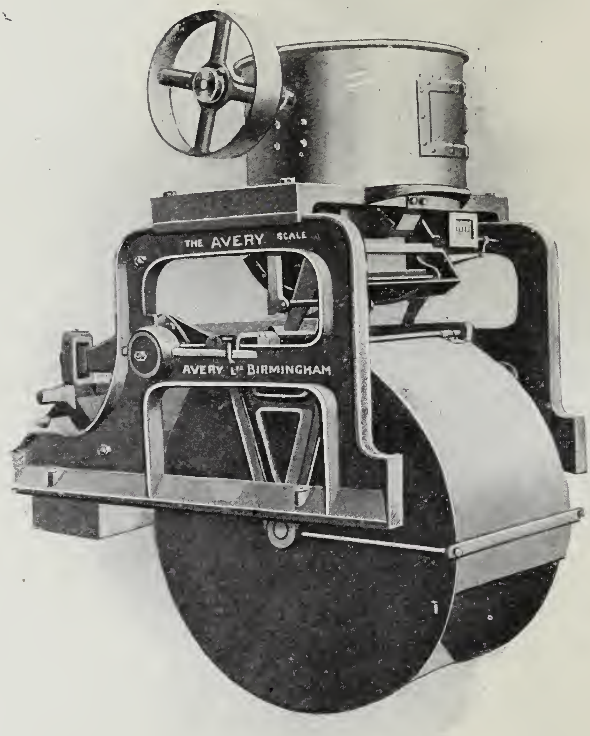

Fig. 88.—Rotating Weigher.

dead centre, when the dead weight of the valve causes it to move forward, thus cutting off the supply of material. At this moment the beam is in equilibrium. In its forward motion the valve knocks away a catch, and the hopper, which is supported slightly behind its centre of gravity, tilts forward, uncovering its outlet. The material as it falls from

the hopper impinges on a rocking plate, which brings down a hook that holds the hopper open until completely discharged. When the rocking plate regains its former position, which it does so soon as the material ceases to fall, the hopper tilts back and, rising, opens the inlet valve.

This machine is suitable for weighing material in any stage of reduction, and, as will be seen from the illustration, Fig. 87, it is compact in form.

A new type of weigher is being introduced for weighing material in a fine state of division. The hopper is divided into three compartments, and revolves one-third of a revolu-

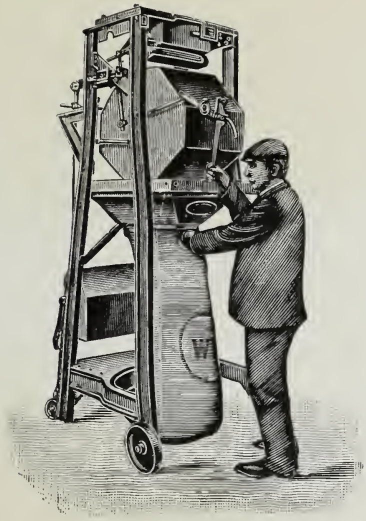

Fig. 89.—Nett Sack Weigher.

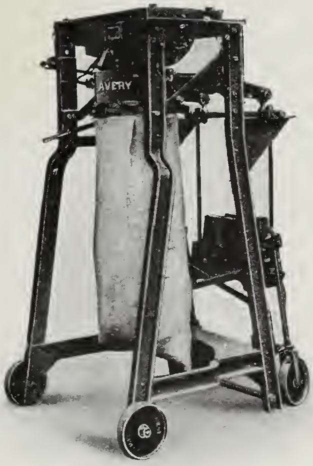

Fig. 90.—Gross Sack-Weigher.

tion to discharge a compartment. The feed hopper is provided with a form of stirrer to prevent the material clogging, and beneath there are the regulating valves. The weighing hopper is supported from one arm of the beam and the weights from the other. The material to be weighed falls into one of the compartments, the feed being cut off as the hopper descends. When in equilibrium, a catch is raised and the hopper turns through a third of a revolution, and the compartment is discharged. The beam then rises and the next compartment is filled.

Machines are constructed which automatically weigh

sacks of material. These are of two types, in one of which the machine first weighs the required quantity of material discharging it into the sack, while in the other the material is filled into the sack until the required weight is reached, when the supply is interrupted.

One of the former type is illustrated in Fig. 86. As will be seen, it is a combination of the Avery grain scale with a hopper chute to which the bag is secured. In Fig. 87 another machine manufactured by the same firm is shown. In this case the bag is securely fastened by means of a strap and buckle to a trunk supported from one end of the scale beam, from the other the weights are hung. The filling operation is started by means of a lever, and when the required weight is reached the supply of material is cut off, the mechanism employed being precisely similar to that used in their grain scale. The full bag is removed and replaced by an empty one, the lever is then pulled over and the filling operation again commences.

Fig. 91.—Simon's Dustless Sack Filling and Weighing Machine.

The Simon's bag filling and weighing machine is of simple construction and in design follows closely the automatic weigher manufactured by this firm, which has been so extensively employed. The bag is secured to a trunk suspended from one arm of the beam, while the weights are suspended from the other. The filling operation is started by pulling down a lever; the cut-off being automatic and taking place when the filled sack balances the weights. All filling and working parts are protected from dust, while the machine is so constructed as to be dustless in operation. The speed at which this machine works is considerable, four bags being filled by it in one minute.

A type of sack filler and weigher extensively employed on the Continent is shown in Fig. 92. It consists of a distributing chute in the form of an inverted Y connected

by means of canvas hose to two short cylinders, round the necks of which the sacks are fastened by means of a strap and toggle. The sacks and their connecting pieces are supported at one end of the balance beam, while the weight is hung from the other. In operation, the cement is fed by means

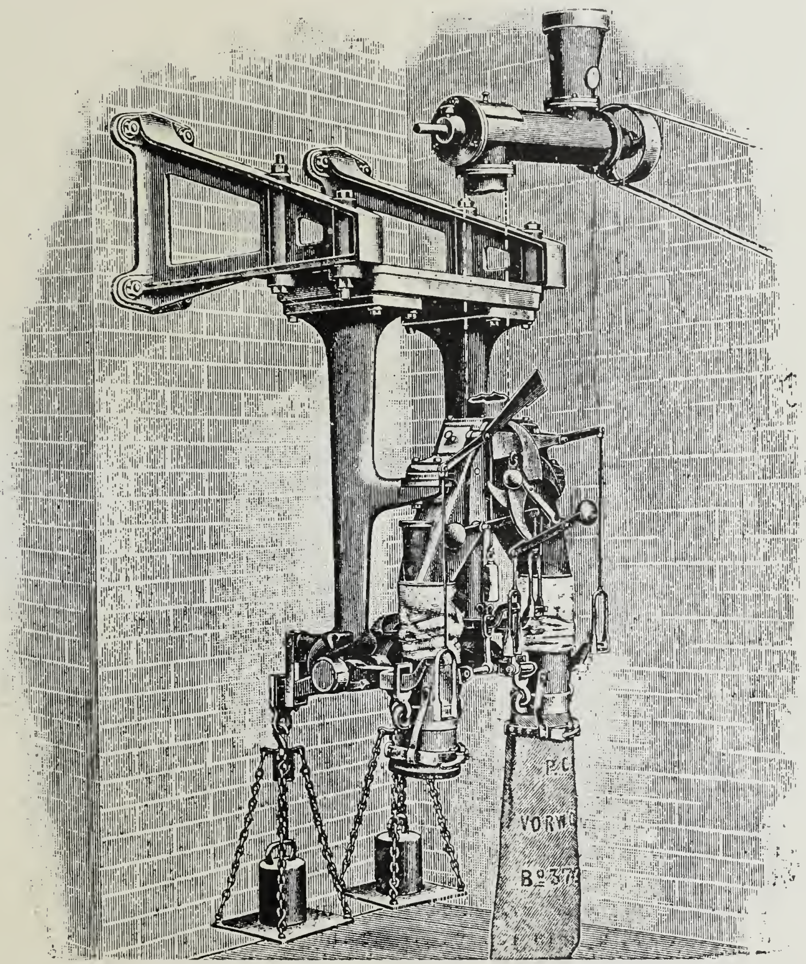

Fig. 92.—Double Sack Filling and Weighing Machine.

of the conveyor into the distributor, passing into one of the sacks, and as the weight of the sack being filled, increases, the balance beam moves downward until, when the sack is filled, it comes into contact with a stirrup and alters the position of the distributing valve, diverting the cement into the other

sack. The filled sack is removed on a sack barrow and is replaced by an empty; meanwhile the other sack has been filled and the operations are repeated.

An automatic sack filler and weigher of novel design has recently been introduced. The sack is suspended from a sleeve inside a cast-iron chamber. The sleeve is suspended from one end of a beam, while the weights are suspended from the other. The weigher is connected by means of a hose to the source of supply of the material. The chamber in which the sack is suspended is connected with an air pump, which, exhausting the air, causes the material to pass into the sack until the required weight is reached, when the connection with the pump is interrupted by means of a valve attached to the balance beam. The door of the chamber is opened when the sack is filled, and an empty is attached in place of it, after which the cycle of operations proceeds as before.

To protect the workmen from dust it is advisable to connect these weighing machines with some form of dust collector by way of a pipe connected to the filling chute, or hoods connected to the exhaust trunks may be arranged near the machines. Automatic cask filling and weighing machinery has been extensively employed both on the Continent and in America.

As an example of this class the machine illustrated in Fig. 93 may be described. The cask is placed on a light platform which is connected with a shaft by means of cords. To one end of this shaft a drum having a spiral channel is keyed. A weight equal to the gross weight of the packed cask and the platform is secured to the spiral drum. At the commencement of the filling operation the cask is placed upon the platform, which is raised until it surrounds the sleeve; by throwing in the clutch the packing worm surrounded by the sleeve is then rotated by the bevel wheels from the pulley, and presses the cement entering by means of the chute into the cask. The cask then gradually descends until, when filled to its correct weight, the clutch is automatically released and the cask is removed and replaced by an empty one.

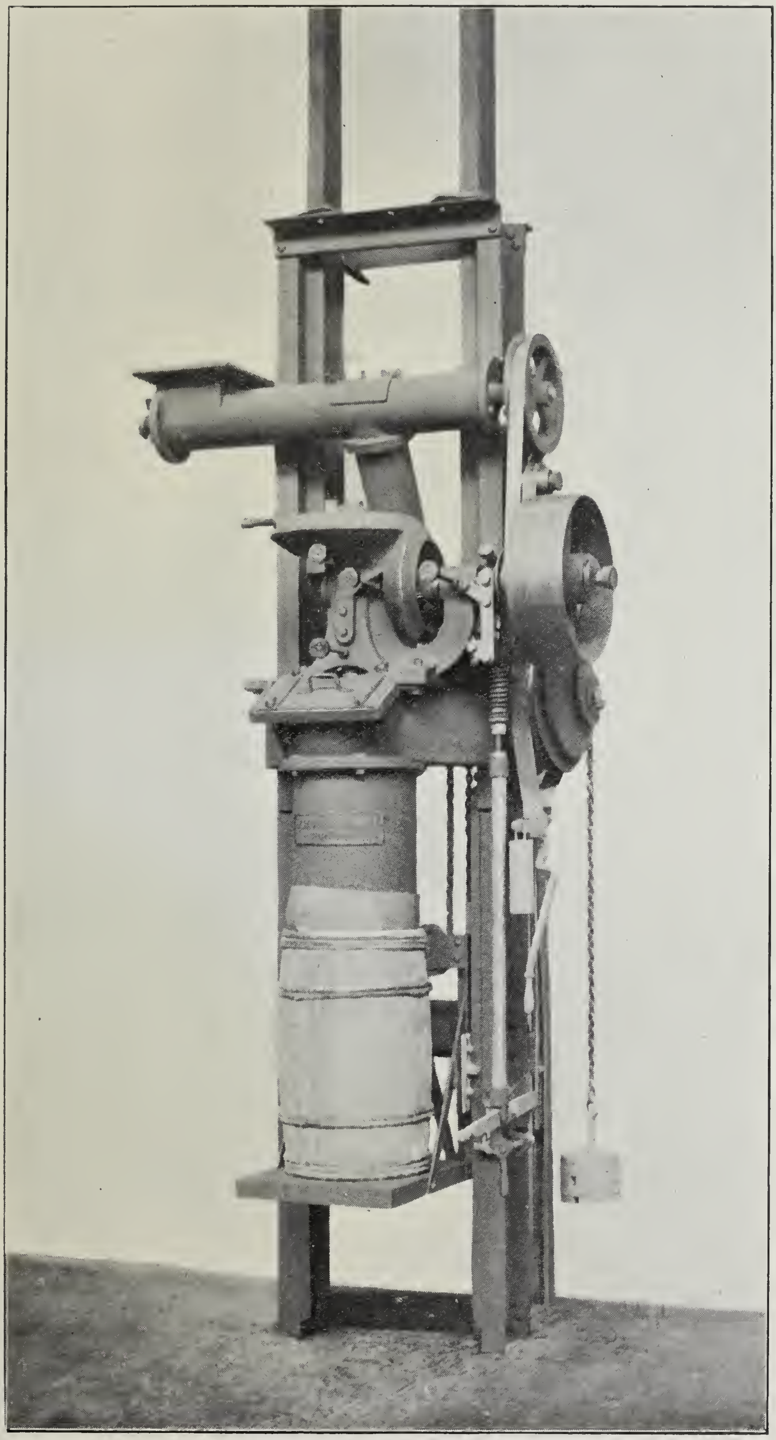

Fig. 93.—Automatic Cask Filling and Weighing Machine.

These automatic weighers are provided with a counter which records the number of weighings made and therefore the amount of material passing the machine. The cask and bag weighers are often arranged on stands or are provided with carriages running on overhead rails, by which means they are rendered easily transportable from one bin to another.

A type of automatic weigher suitable for weighing raw material, finished or semi-finished products, is the Blake Denison weigher. It is unique in principle, and does not make use of a hopper of any kind, but makes a series of weighings of the material on the conveyor and registers the total of the weighings thus made. The types of conveyor with which this machine operates includes the belt, plate, and bucket conveyor.

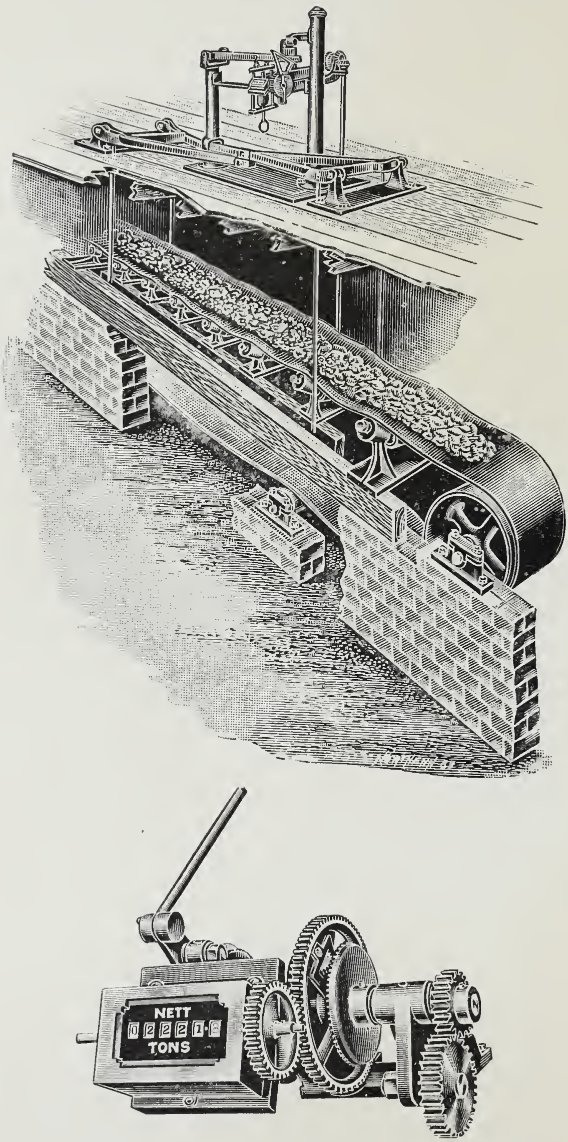

Fig. 94.—Blake Denison Conveyor Weigher.

The operation of the machine is as follows:—A section of the conveyor, often a six feet length, is suspended from a steelyard, weighted so as to counterbalance the unloaded

section. The end of the steelyard is raised from its zero point by the load on the conveyor to an extent equivalent to the load ; in this position it is gripped and the load is registered. The length of the conveyor which has been weighed passes on (there is no interruption of its motion) and when a new length is on the suspended track another weighing is made, the result being added to those previously recorded.

The machine and the counter is illustrated in Fig. 94. A mercury dashpot is employed to damp any oscillations, and the ball beneath is of such a weight as to compensate for the weight of the unloaded section.

The cycle of operations is as follows :—

1. Steelyard takes position indicative of load.
2. The gripping levers hold it in this position.
3. Measuring quadrant moves forward until it comes in contact with the steelyard.
4. The quadrant moves back, rotating by means of pawls secured to it the ratchet registering wheel which by gearing registers on the counter a figure representing the height to which the steelyard has been raised.
5. The steelyard is then released and when the weighed length of conveyor has been replaced by a new section the cycle is repeated. The gripping levers, &c., are driven by means of suitable gearing from the conveyor itself.

The machine is particularly adapted for employment when sticky materials and large lumps have to be weighed. A point of importance is that no part of the machine comes into direct contact with the material weighed.

CHAPTER XI

SEPARATORS AND AUTOMATIC FEEDERS

A variety of accessory plant is employed in dry grinding-mills to assist the various machines in the production of a satisfactory product, with additional convenience to the workmen and economy to the manufacturer.

One means of obtaining increased efficiency of the various grinding machines is by abstracting, so far as is possible, from the material supplied to them all particles of a size similar to that which they will normally produce. This is accomplished by the use of screens suitably proportioned to separate that which is too coarse or too fine to be treated by them.

One of the oldest forms of such appliances is the rotary screen or "*trommel*," and its employment is almost entirely restricted to the separation of large lumps. It is so well known that it scarcely needs description. For completeness, however, it may be described in its more recent construction. It consists of a cylinder formed of perforated plate suitably stiffened by the use of longitudinal channels and provided with roller paths. It is supported by means of these rings in a slightly inclined position on friction rollers, and is rotated by driving one set of these rollers from a countershaft or by means of a circular rack. At the upper end a cylinder of steel plate surrounds the perforated plate, the object of which is to divert such particles as pass through the screen and deliver them at a certain distance from the feed end. By arranging zones of perforated plate with different sized holes the material fed into them may be divided into a number of grades. In the cement industry, however, they are usually employed for producing only two grades of product, and hoppers and chutes are provided for collecting the tailings and the fines. This form of screen is

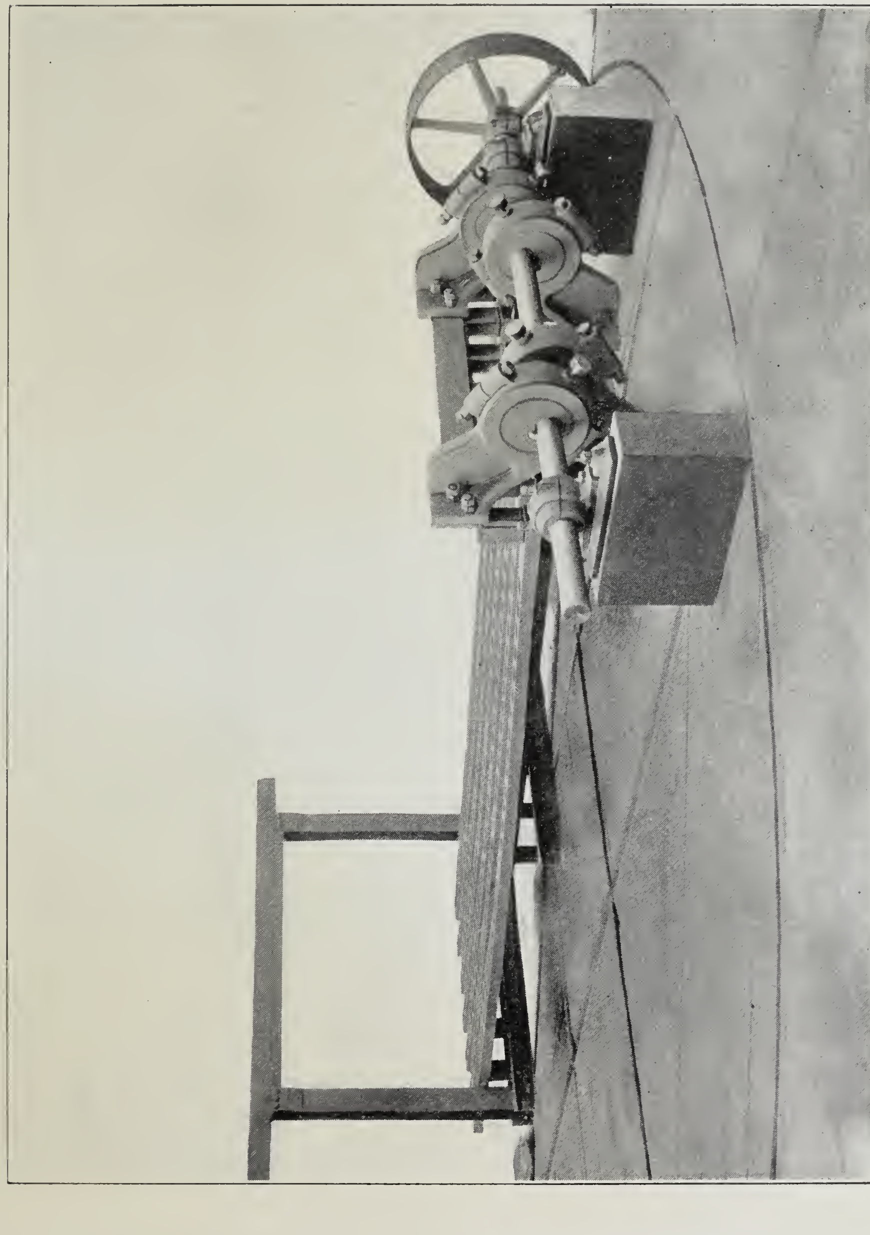

FIG. 95.—Sorting Grate.

most suitable for separating material in fair sized lumps, about the size of shingle, and it is consequently used before the crusher, the fines passing direct and the tailings by way of the crusher to the drier.

Oscillating screens are often employed for a similar purpose. They are provided with perforated plate for the purpose, or a grating formed of bars is used. The grating

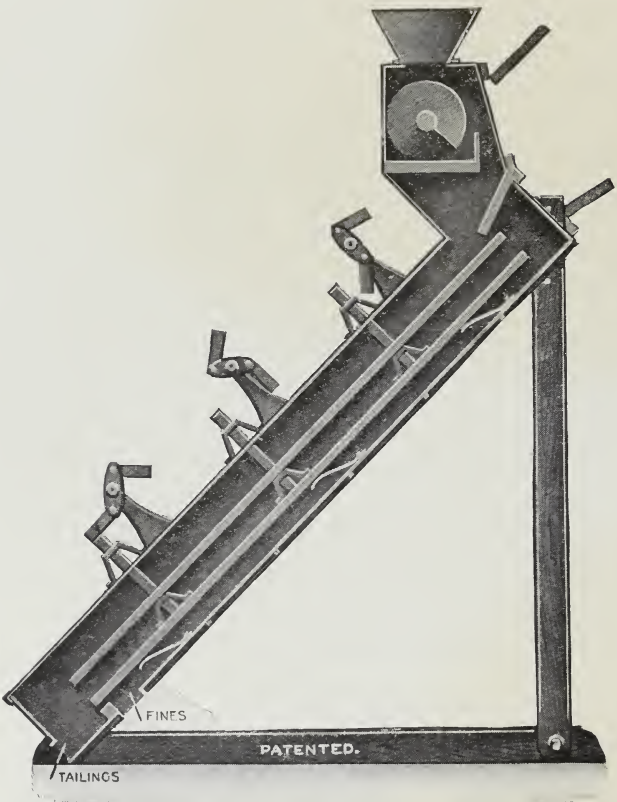

Fig. 96.—Section of Newaygo Separator with Guard Screen.

is arranged in an inclined position with the alternate bars arranged in two sets, reciprocated alternately by means of eccentrics secured to a driving shaft, one set moving forward while the other is returning. In this way the larger pieces are propelled over the edge of the grate, while the smaller pass between the bars. The construction of this form of sorting grate is shown in Fig. 95.

A number of grinding machines give a product which contains a large proportion of fine stuff together with a certain percentage of large nibs. A material of this kind cannot be economically reduced in a tube-mill unless the larger particles are separated. Instances of this type of machine have already been given, and the separators used in conjunction with them have been cursorily noticed. The appliances which can be used are reels, oscillating or vibrating sieves, and air separators.

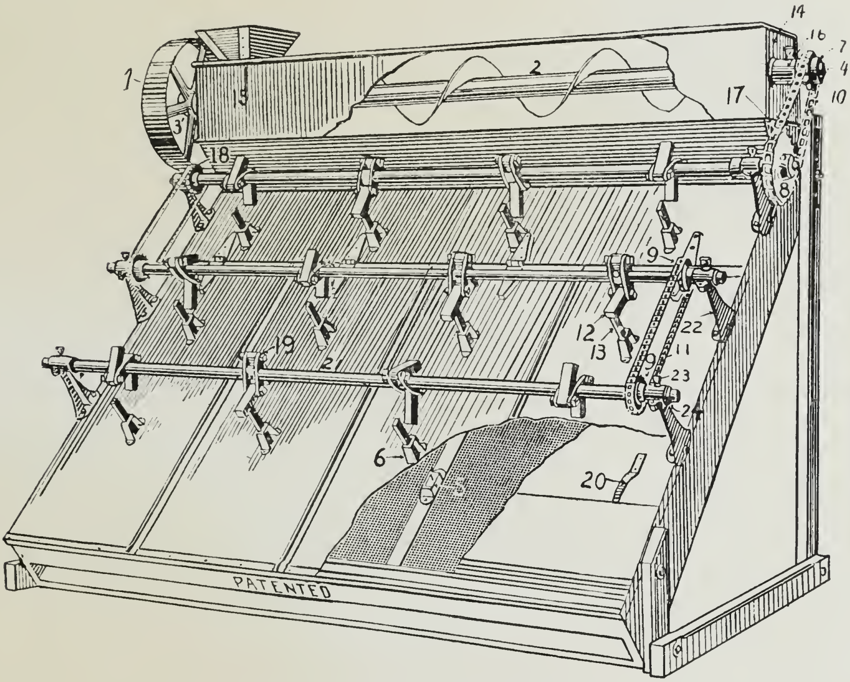

Fig. 97.—The Newaygo Separator.

Reels, oscillating and vibrating sieves are chiefly useful in separating large nibs, as when employed for the finer sifting operations, they have a tendency to clog, and when some mechanical means for cleaning them is provided, the wear is often excessive. The reel is either a rotating cylinder or a prism of polygonal section into which the material is fed. It is surrounded by a steel or timber casing, the fine material being collected by a screw conveyor and the tailings passing by means of a separate chute back to the mill. At times the

reel is fitted with tappers which serve to dislodge material which adheres to the fabric and would otherwise choke the holes. The oscillating and vibrating sieves are inclined at an angle of 45 deg. The mechanism employed for oscillating the screen varies in the machines supplied by different

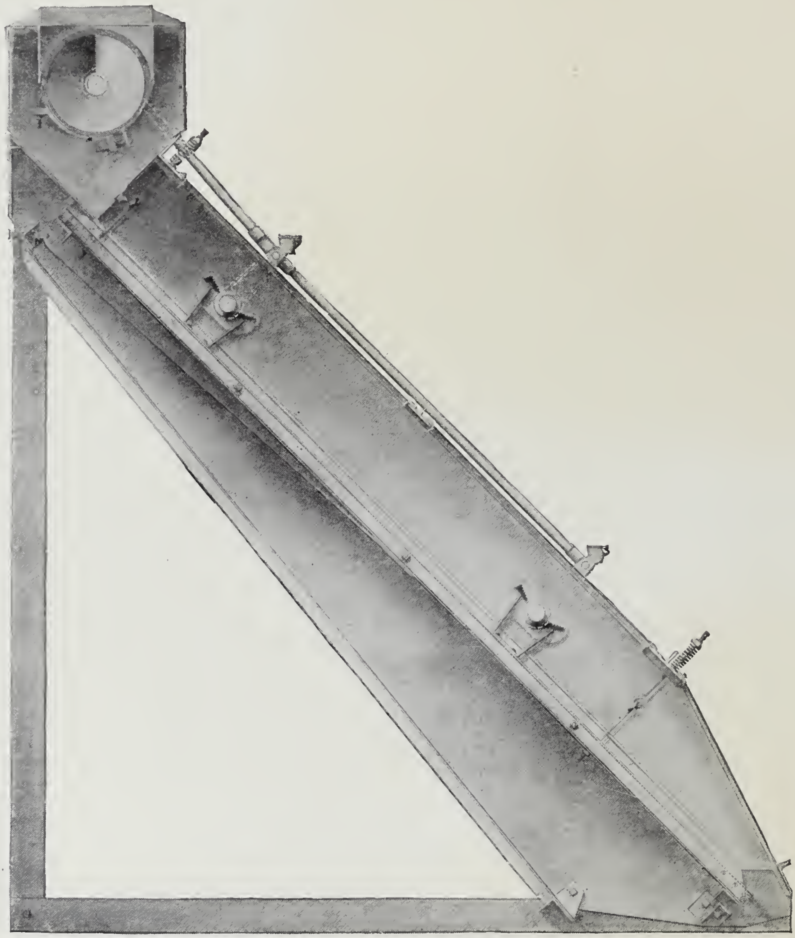

Fig. 98.—Section of Perfectecon Separator.

manufacturers; as a rule some simple application of a cam or eccentric is made use of.

A type of separator which has recently been somewhat largely employed is the Newaygo separator. It consists of an inclined screen provided with a number of rods placed in three rows and projecting through the casing. Three shafts

provided with tappers are so arranged that as the material is fed on to the screen by means of a spiral conveyor the tappers, hitting the heads of the rods, vibrate the screen.

This type of screen is sometimes provided with a coarse meshed guard-screen, which materially reduces the amount of wear upon the wire. The design and operation of the Newaygo separator is well shown by Figs. 96 and 97.

Another form of vibrating screen is the Perfectecon, which is illustrated in Figs. 98 and 99. The frame and casing of

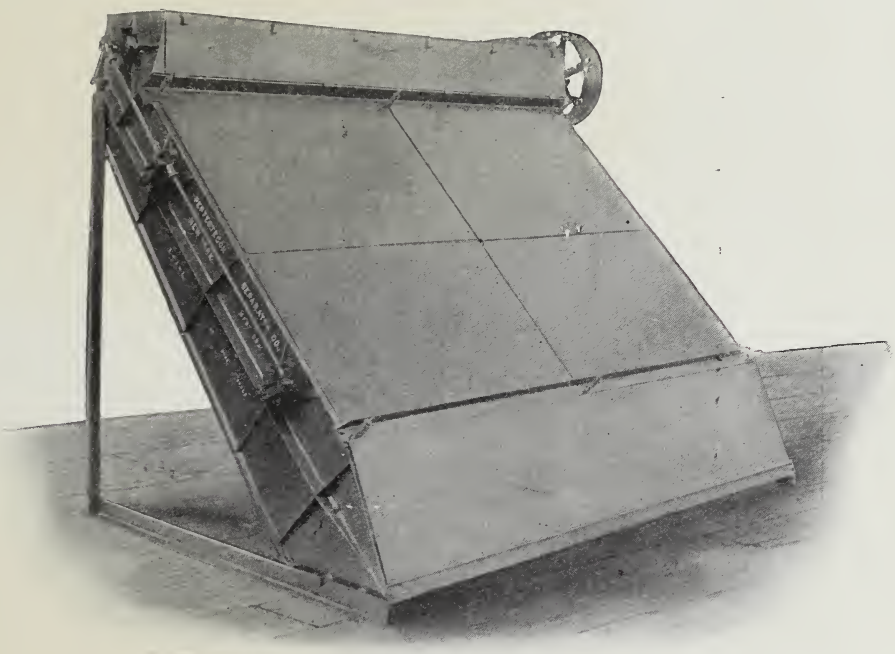

FIG. 99.—Perfectecon Separator. General View.

this machine is constructed of cast iron and steel, while the tapping mechanism is operated by a crank and connecting rod rocking the vibrators. A point in the design of this screen, which is worthy of mention, is the feeding mechanism. A worm conveys the material along the upper edge of the screen, and the trough is so formed that it will feed the material from left to right or *vice versâ;* this end being arrived at by making the trough in section so that the opening can be left on one side or the other. By this means

the number of duplicate parts it is necessary to keep on hand are reduced.

Within certain limits the fineness of the product of this type of screen can be varied by altering the inclination of the screen. For greater alterations the employment of different meshed wire cloth must be resorted to. The product of these screens is always much finer than the mesh would indicate—for example, using a 20-mesh cloth, the material produced would give no residue on the 40-mesh sieve. As an indication of the character of the product obtained by using different wires, the following table may be of value :—

Fineness of Finished Product.	Mesh of Cloth Used.	Gauge of Wire.	Output of Screen, 60 sq. ft. Surface.
			Tons per Hour.
4	3	13	18
8	4	14	16
10	5	16	15
16	8	18	13
20	10	20	12
30	14	22	11
40	20	26	8
50	24	26	7
60	30	31	6
80	40	33	3
100	50	35	2
120	55	36	$1\frac{3}{4}$
140	60	37	$1\frac{1}{2}$
160	70	37	$1\frac{1}{4}$
200	70	37	1

The use of woven sieves becomes increasingly costly as their fineness increases; at the same time the difficulty of sifting materials liable to clog the sieves is also increased. The result is that sieves having more than fifty holes per lineal inch are not used to any extent in the cement industry.

To separate finer particles than can be removed by such a wire sieve some other separating system must be adopted For such a purpose separation by means of a current of air is well adapted. The Mumford and Moodie air separator was introduced many years ago, and since then it has suffered

several alterations in design. The patents having expired, this separator is manufactured by a number of firms.

The illustration, Fig. 100, gives a clear idea of its construction and operation. The material to be sifted is fed into the hopper-shaped opening at the centre of the top plate and falls upon the rotating spreader. By this means it is thrown outward in a thin sheet and air is drawn through the spray of material by the fan, and is delivered by it into the outer

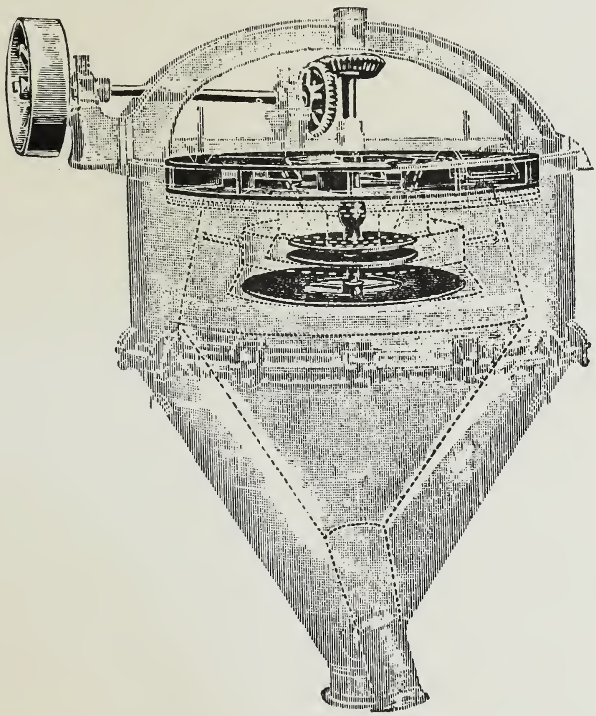

Fig. 100.—The Original Moodie Air Separator.

casing. The current of air carries with it the finer particles. These are deposited in the casing, and by means of a chute they are delivered to transporting mechanism, the air passing back through the stream of material to the fan. The coarser particles fall and are collected by means of the inner casing, from which a chute leads them to the grinding-mill. The fineness of the product turned out by this separator is varied by means of a circular damper which reduces the velocity of the air passing through the stream of material.

Other means employed, to the same end, by different manufacturers, consist in altering the speed of rotation of the fan, or varying the angle at which the blades are set. Many attempts have been made to obtain a sharper separation of the coarse and fine particles than can be obtained with the foregoing machine. Moodie has patented a system of dividing the air stream, carrying the particles into a number of layers. In this modified form, the air separator consists of a spreader extending nearly to the outer casing, and beneath this a number of rings of sheet steel are arranged with spaces between: below this the fan is arranged. In operation, the material is fed on to the spreader plate, and is driven outward, into the space between the inner and outer casing. The rotation of the fan causes a current of air to travel through the stream of material, and the dust-laden air is divided by the number of metal rings, which being also rotated drive out, by centrifugal force, the coarser particles, while the fines are delivered into the inner casing. This separator is sometimes called the Selector.

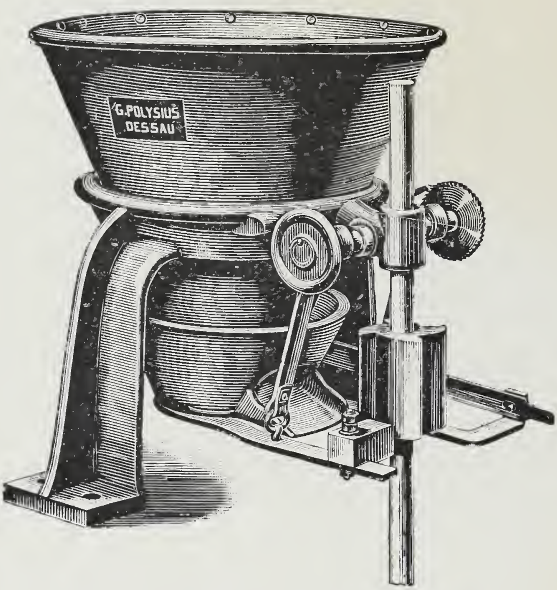

Fig. 101.—Shaking Feeder for Millstones.

In another type, a number of deflecting rings cause the material to be split up into a number of streams, the coarse particles fall in the inner cone, while the fines pass into the outer casing and the air passes back, by way of specially arranged ducts, to the fan.

Other types of air separators are in use but to a much smaller extent than are the foregoing.

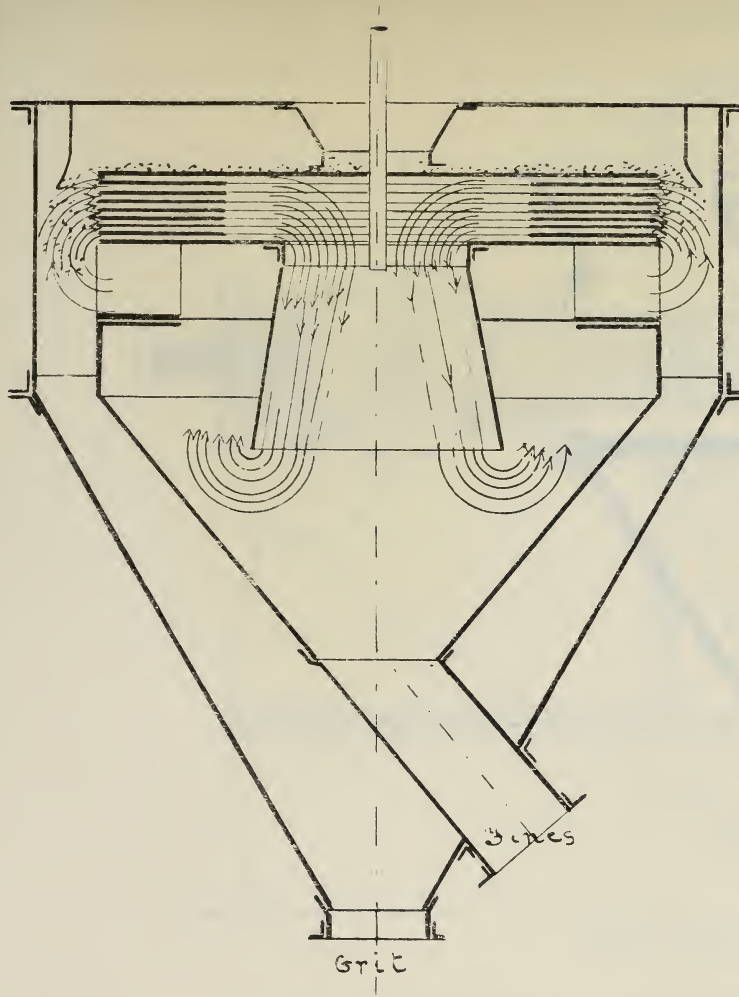

Fig. 100a.—The Selector.

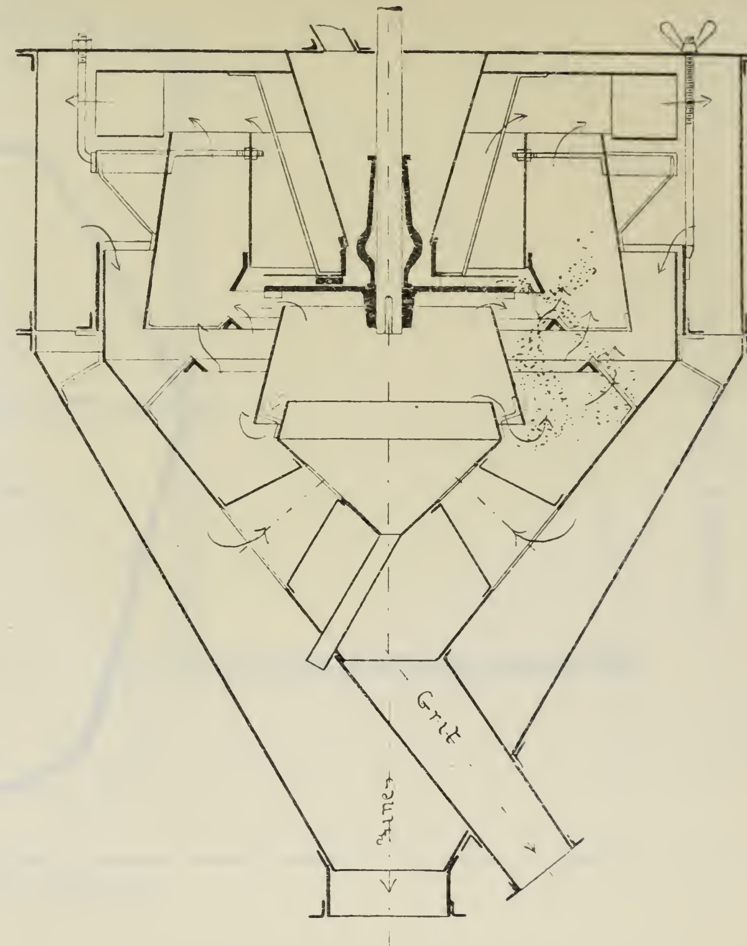

Fig. 100b.—Orion Compound Separator.

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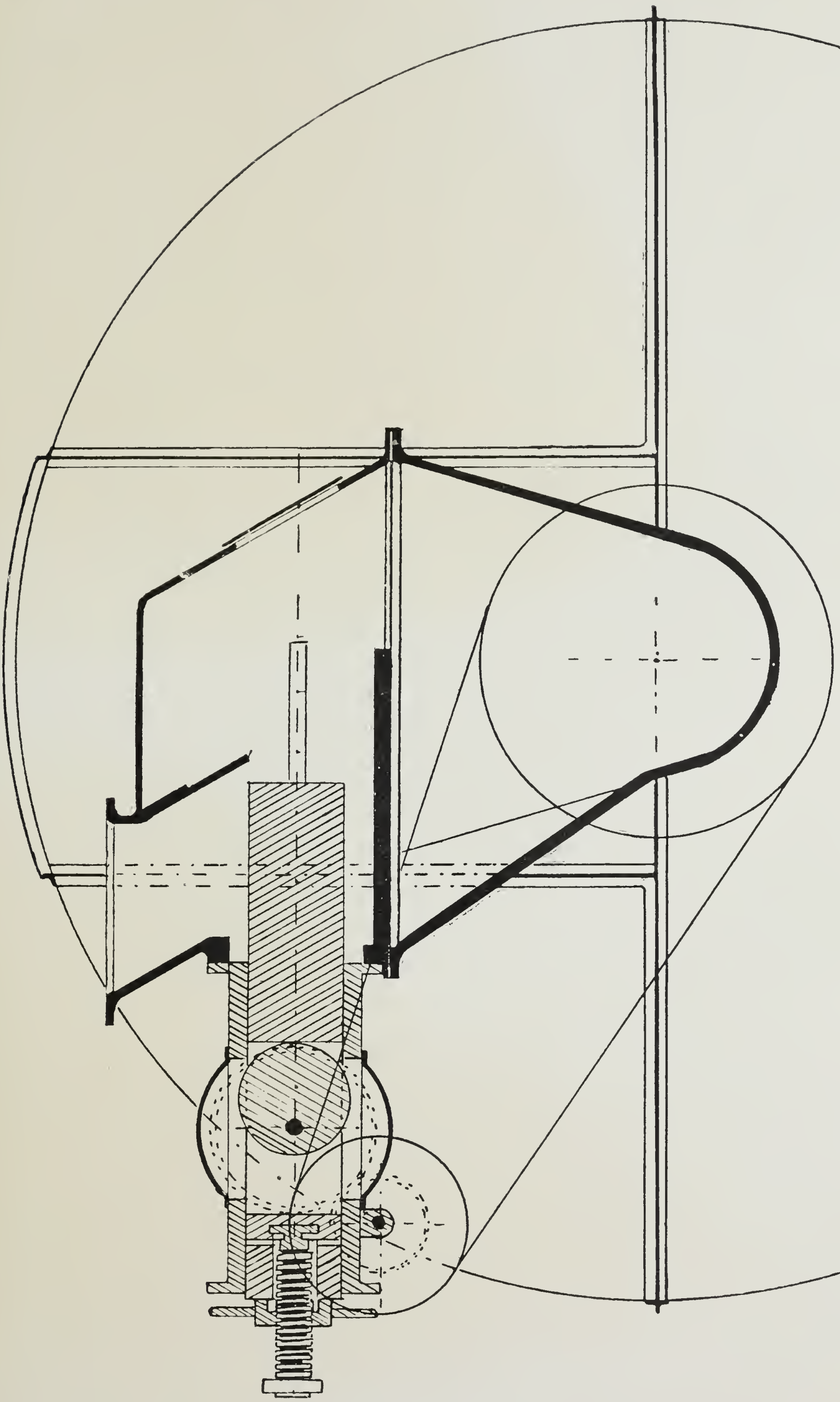

FIG. 102.—Piston Feed as applied to Ball-Mill.

The Raymond air separator consists of a chamber shaped like an inverted cone; inside this another cone is arranged concentrically with the first. The air passes in near the apex of the outer cone; and the material to be separated is delivered just above it. The air passing upward between the conical casings carries the finer particles with it. The finest particles pass by means of a centrally arranged pipe to the fan, those which are somewhat coarse, settling in the inner

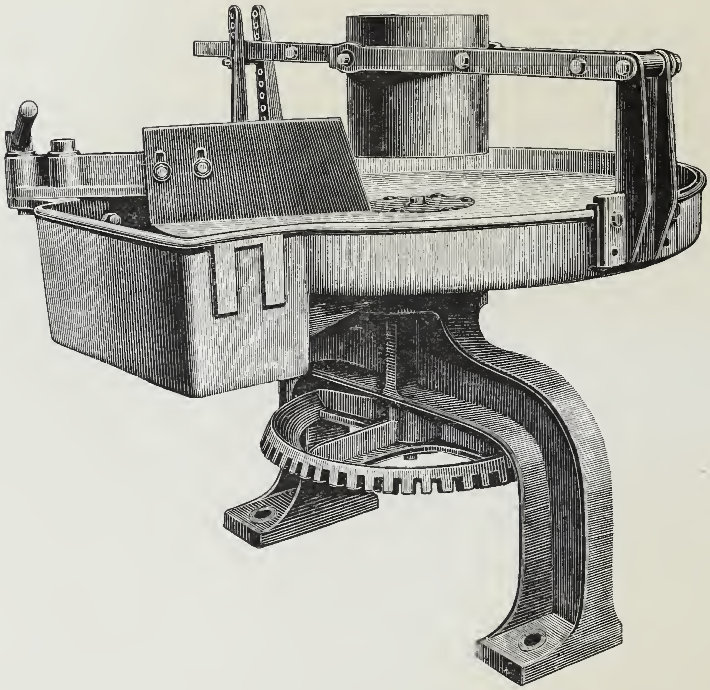

Fig. 103.—Table Feed.

cone, descend to the outlet. The air containing the finest particles passes from the fan to a cyclone where the solid matter is deposited, the air passing back to the separator.

A factor influencing the output of the mill and the uniformity of the product to an equal, if not greater, extent than does the uniformity of the grading of the feed, is its uniformity in quantity.

For this reason the majority of mills are provided with some attachment for introducing the material to be ground

in regular quantities and at uniform intervals. The wash-mill is a machine which is often very badly treated in this respect, and as automatic feeders for them have not been employed, care should be taken to obtain regular feeding by proper oversight of the gang. Large table feeds have recently been constructed for feeding clay to brick machines, and it is possible that similar appliances may come into use in connection with wash-mills.

For millstones a shaking feed of simple form is employed. One design is illustrated in Fig. 101. It consists of a small hopper provided with a tray below. This tray is supported by a pin at the rear and by means of straps secured to a spindle in front. A fork projects from the tray and to one leg a pallet is attached which bears against a cam fixed to the damsel. A spring secured to the other branch of the fork keeps the pallet in contact with the cam. On setting the mill in motion this cam rotates, imparting to the tray a shaking action; by varying the distance between the tray and hopper by means of the straps connecting it with the spindle, which is provided with a ratchet engaging with a pawl, the size of the feed may be varied. Worms or spiral conveyors are often used for uniformly feeding material from storage hoppers to the various machines. This type of feed is employed in the Fuller, Griffin, Bradley, and tube-mill. Occasionally it is employed for feeding the ball-mill but most usually some other type of feeder is employed for this purpose. In the section dealing with kilns it will be seen that the worm conveyor is used in the coal feed and in the raw meal feeder.

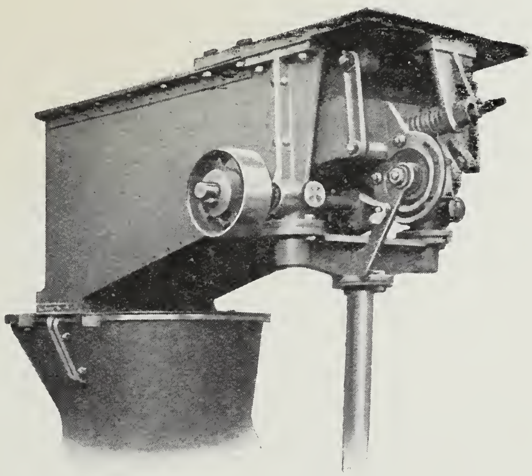

Fig. 104.—Shaking Feed.

By means of a variable speed gear, such as Reeves pulleys or the simple stepped cone pulley, the rate at which material is delivered by the worm can be altered at will: the stepped cone being all that is required for mill feeding.

The piston feed is often employed for feeding material to the ball-mill; it consists of a hopper-like chamber the bottom of which is provided with a piston reciprocated by an eccentric or by a bell crank lever which is operated by the central shaft of the mill. The stroke is varied by means of a nut working on a screwed spindle to which a hardened steel pallet is secured. This form of feed gear is also suitable for delivering material from the bottom of silos used for lumpy material. The roll feed consists of a pair of rolls having deep longitudinal channels machined in their periphery. They are extremely simple in form and need no special description. It may, however, be stated that they are unsuitable for employment with material liable to cake or clog.

The table feed consists of a rotating table on to the centre of which the material is delivered from a hopper. A knife or scraper, one end of which is hinged to the casing surrounding the circular plate, cuts off any desired proportion of the material lying on it. In some types a sleeve is also provided which can be raised or lowered and the amount of material delivered can also be varied in this way. This movable sleeve has also the advantage that large lumps can be removed with ease by raising it.

Many forms of shaking feeds are employed. One has already been referred to as a device used in connection with millstones. A form which is extensively employed for feeding lumpy material to ball-mills and pre-grit mills is illustrated in Fig. 104, from which its mode of operation can be easily understood. A cam recipocrates the tray secured to the pendulum-like supports and the amplitude of the oscillation is varied by altering the position of the pallet.

CHAPTER XII

PRESSING AND DRYING THE RAW MATERIALS

In the introductory chapter it has been said that the machines used for briquetting the raw materials fall into three classes: those which deal with plastic, semi-dry, and dry material.

The plastic brick-making machine consists essentially of a chamber in which a spiral revolves forcing the material fed in through a mouthpiece or die in a long stream, from which bricks are formed by cutting it by means of wires. Such a combination is shown in Fig. 105. The stream of clay issuing from the die is received on the fustian or felt covered rollers

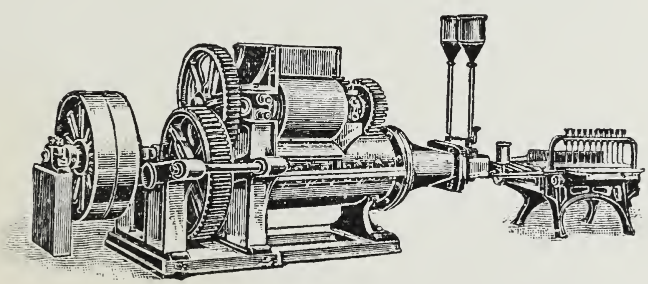

Fig. 105.—Plastic Brick Machine.

or a water lubricated table which allows it to move forward. When a certain length has issued it is cut off by means of a steel wire, held in a form of bow, and the mass is pushed forward to a table where it is cut by a set of wires into a number of bricks. The pug-mill and the cutting table are made in a large number of forms, each of which have their adherents.

The material treated by this class of machine contains from 18 to 25 per cent. of water. For drier mixtures machines of a different type are employed. In this class,

machines utilising the effect of a falling stamp are common. With them the material containing from 8 to 10 per cent. of water is delivered into a box-shaped die, and the stamp then consolidates the mass, after which the brick is ejected by the rising of the piston, the face of which forms the bottom

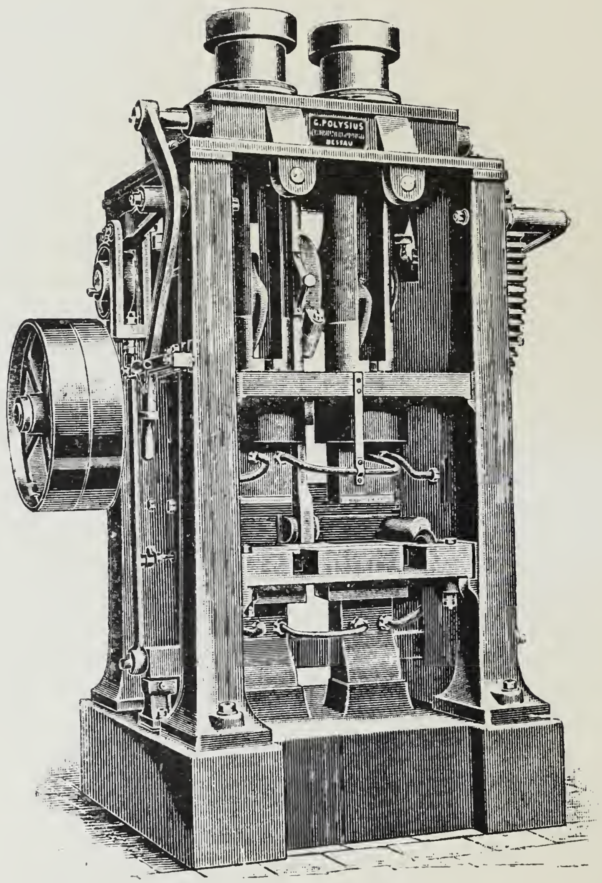

FIG. 106.—Drop Stamp Press.

of the mould. A machine of this type is illustrated in Fig. 106.

As ordinarily constructed, the machine has two dies, but machines provided with four are also made. It consists of a heavy framework and sole plate which serves to support the anvils. The stamps are heavy iron castings and slide in long guides. The stamps are raised and then allowed to fall by

means of cams, after which operation the anvils are raised and the bricks ejected. The filling gear then moves forward thrusting the finished bricks out of the way and the damped meal then descends into the mould, after which the filler moves backward, the cycle of operations being repeated. With this machine all the surfaces are heated, and thus the adhesion of the materials to the die is prevented. A double stamp machine will produce 1,500 bricks of normal size per hour, requiring about 3 horse-power for its operation. With this machine each brick receives two blows which, combined with the weight of the stamps, ensures solidity.

The Dorsten press has been largely used for briquetting cement materials. It is of the drop stamp type and is designed with two or four stamps. It differs from the previous machine principally by having the ejecting and feeding gear actuated by a separate shaft driven by gearing from the main shaft.

Almost any type of dry press can be used for the production of briquettes from the cement raw materials, and those which give direct pressure by means of toggle levers, cams, or by direct hydraulic or steam pressure have been employed. Machines working with high pressures may be used for the production of briquettes from "lean" or "short" materials, or they may be employed for working up material with only about 5 per cent. of water.

A machine of somewhat unique form is illustrated in Fig. 107. It produces briquettes of spherical form. The material is fed to the dies by means of a hopper, and by means of a powerful ram the briquettes are thoroughly consolidated. This machine produces two briquettes per stroke, or about forty per minute, equal to an output of about 4 tons per hour; the material containing about 10 per cent. of water.

The President dry press manufactured by Messrs Johnson, of Leeds, is a compound lever machine. It forms up to eight briquettes in one operation, and it will produce over four thousand bricks per hour. Its operation is as follows. The material is fed into a hopper at the back of the machine, from which it passes to the feed box which delivers it to the brick moulds. The material is then pressed by the dies

operated by a toggle, the bricks being pressed from both top and bottom sides. The pressing operation is continued until the bricks are discharged from the moulds when they are pushed forward by the filling box conveying a fresh charge to the moulds.

The above machines may be taken as indicating the

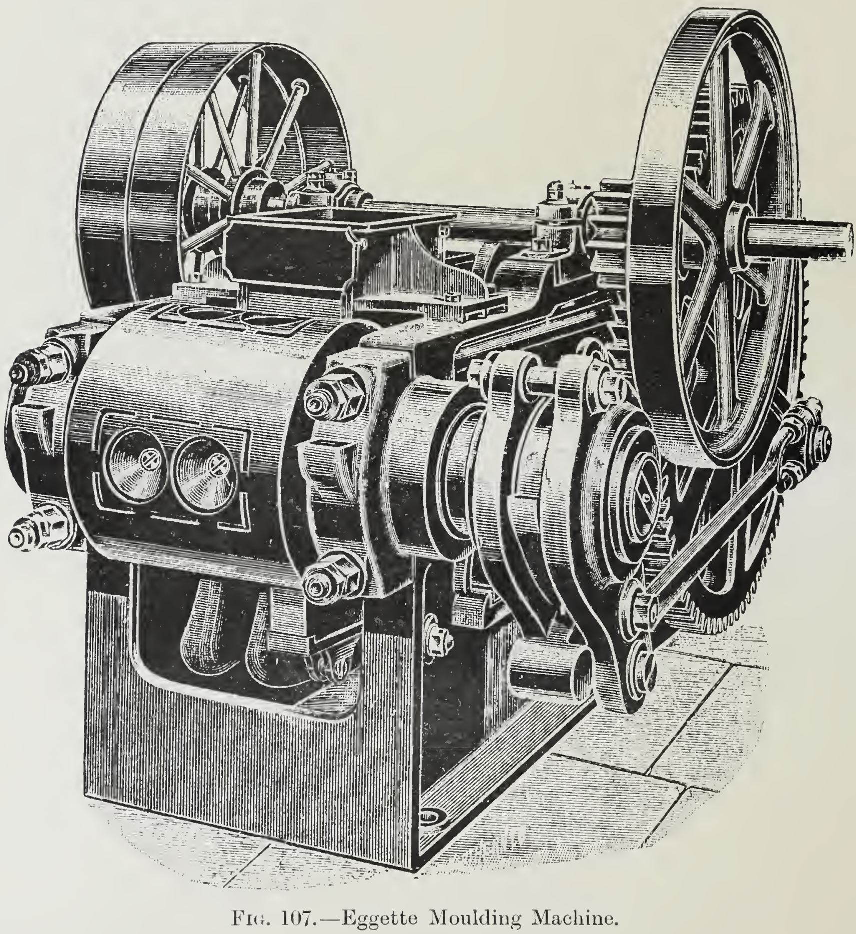

FIG. 107.—Eggette Moulding Machine.

various types of machine suitable for producing briquettes. The choice of any particular form depends to a large extent on the character of the raw material which it is required to convert into briquettes.

The shape and size of the briquette is a matter of importance. Frequently the material is moulded into bricks of the

size and form of those used for building purposes, but half bricks are largely employed because they present a greater surface in relation to their volume. The sharp corners of a brick in the form of a rectangular prism are, of course, weak and tend to crumble, whereas those in the form of short cylinders, spheres, or eggettes are freer from this objection and at the same time they descend the kiln shaft more easily. For such reasons one or other of the latter forms are frequently employed when continuous shaft kilns are

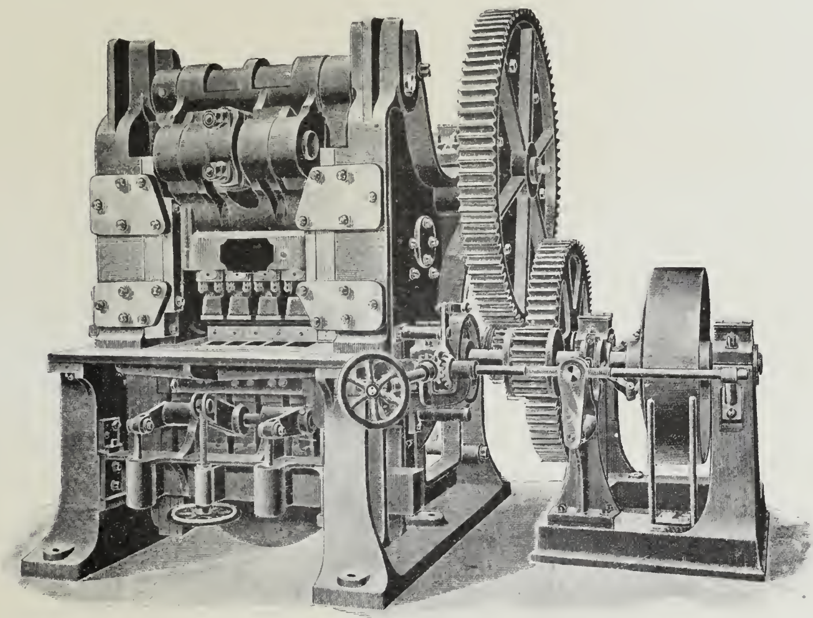

Fig. 108.—President Dry Press.

used. For ring kilns those in the form of the ordinary brick are more satisfactory.

In many cases the material is only formed roughly into lumps, and this often as not by merely breaking up the dry slurry from the flat. Continuous kilns, however, require well consolidated briquettes, and those formed by the cruder means are not sufficiently strong.

The system of forming the raw mixture and fuel together into briquettes has been largely adopted, and in such cases an exceedingly cheap form of fuel—coke breeze—is employed.

The pressing of the mass in this case requires no special description, the requisite proportion of breeze being merely intimately mixed with the material and the whole mass pressed.

In certain instances a small percentage of lime is added to the raw mixtures to bind them. For example, with slag limestone mixtures such an addition is essential, as of themselves the materials have no tendency to bind. In this connection it may be mentioned that Wood, of Middlesbrough, attempted to produce Portland cement from slag and limestone, and failed on account of the friable nature of his briquettes. Ransome, in his experiments with the rotary kiln, burned some of Wood's mixture successfully, and it appeared that in this form of kiln there was a solution of the difficulty. In Germany the use of lime was resorted to as a binding agent in conjunction with the slag which acted as a puzzolana. This device rendered it possible to utilise the shaft or ring kiln for the same purpose.

The drying of briquettes formed on the plastic system is usually performed in tunnel driers, through which hot gases from a furnace pass. Frequently a fan is used for driving air through the tunnels. Tunnel driers in which steam or hot water is used for heating are also frequently employed. The bricks stacked on cars are passed in through a doorway at one end of the tunnel, and at intervals other cars are pushed in, those which have been previously introduced being gradually sent forward to the exit end. The speed at which the cars pass through the tunnels depends upon the amount of water present in the mixture, and its tending to shrink and crack in drying. While the necessity for obtaining sound bricks is not so great in the case of cement materials as with building bricks, care has to be taken that the bricks are not seriously weakened.

With ring kilns, driers are employed which utilise the heat radiated from the body of the kiln and which would otherwise be lost. For this purpose racks are arranged round the walls of the kiln, or above them, a sufficiently large intervening space to permit of easy operation being left. In this connection it may be remarked that in com-

paring the relative fuel consumption of rotary and stationary kilns, the amount for drying the briquettes in the latter case must be taken into account, as also must the consumption of power and labour in the production of the briquettes when comparing the relative working costs of the two forms of plant. With driers employing waste heat, no extra expense is incurred in drying the briquettes, while, of course, briquettes made by the "dry" process are sufficiently solid as they come from the press, and the drying process, as an individual operation, is then dispensed with.

BOOK III

KILNS

CHAPTER I

SHAFT AND OTHER STATIONARY KILNS

THE kilns in which the raw mixture is clinkered divide themselves into two classes: the one in which the burning operation is intermittent, and the other in which the kiln, having been once lit, operates continuously, fuel and the raw material being fed in to take the place of the clinker withdrawn. The former class of kiln is the oldest, and, although still in use in many works, they can only be regarded as antiquities existing as operating units, merely because their proprietors do not see their way to erect more modern plant.

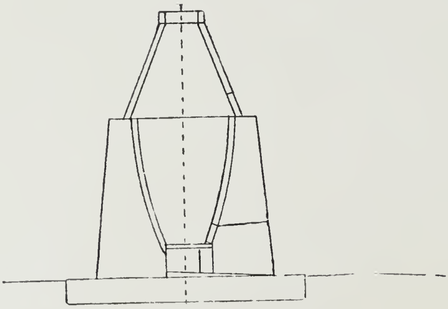

FIG. 109.—Section of Bottle Kiln.

The lines on which the oldest of all the intermittent kilns—the bottle kiln—is constructed in this country have scarcely been altered from the earliest days. Such a kiln is illustrated in section in Fig. 109. It consists of a burning chamber provided with a grate and fire hole at its base, and terminating in a chimney in the form of a truncated cone. The kiln is loaded in the following manner: faggots are placed on the grate, and upon this a layer of coke is deposited; the raw material in lumps, and coke is then loaded on to this in alternate layers by way of the loading

eye situated in the base of the stack. When fully loaded, the loading eye is bricked up and the fire is started. Combustion being well in progress, the fire hole is also closed and the kiln allowed to burn itself out. The kiln and its contents are allowed to cool for some days, and the bars are then knocked out and the operations of unloading and picking commenced. The underburnt portions, pink as they are often called, are separated from the bluish black clinker which goes to the mill, while the former is reloaded with more slurry and fuel into the kiln.

The German type of intermittent shaft kiln differs considerably from the English, being much narrower relative to its height. The lines of such a kiln are shown in Fig. 110. In operation the same cycle of operations proceeds as with the kiln previously described.

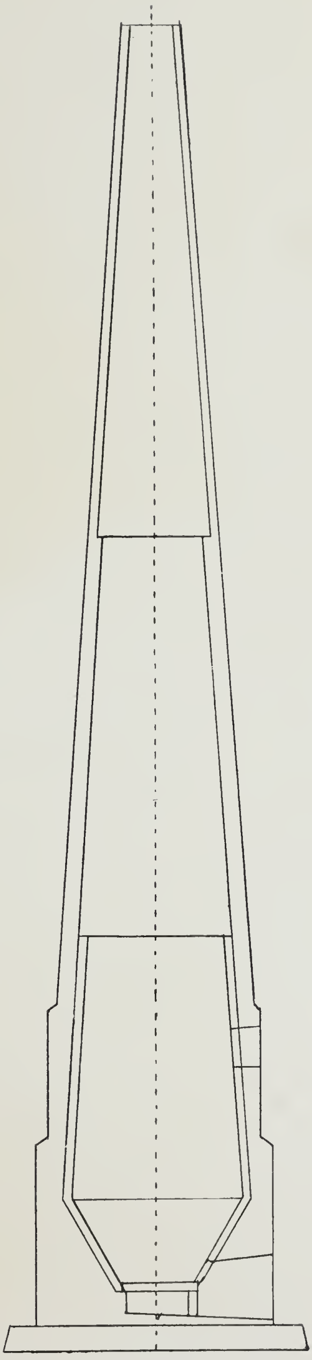

Fig. 110.—Section of an old German Shaft Kiln.

One of the greatest objections to the bottle kiln is the uneven burning to which the contents of the kiln are subjected, a great deal of over-burned and under-burned material always being produced. The quantity of good clinker obtained depends upon the skill of the burner, and the consumption of fuel is affected by the same factor. Even when worked by a good burner the bottle kiln is wasteful of fuel, and the causes of this are patent to the casual observer. First, the gases pass from the kiln at a high temperature and all the heat

contained in them is wasted; secondly, the kiln must be allowed to cool before unloading, and all the sensible heat contained in the clinker and the walls of the kiln is thus lost.

The construction of chambers for drying the slurry or the briquettes of raw material by means of the kiln gases led to a considerable saving, as the cost of fuel for heating separate drying flats or drying chambers was saved by this means.

The Johnson kiln incorporated this principle, and it met with extensive adoption both at home and abroad. The burning chamber of this kiln is constructed on the same lines as the common bottle kiln, but instead of being surmounted by a conical chimney, a long flat flue connected it to a cylindrical chimney. The arrangement of kiln and flue is

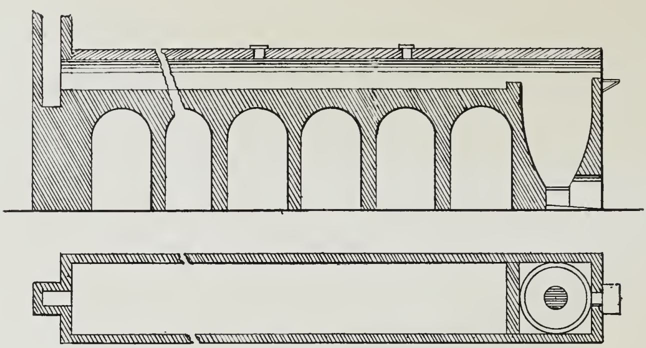

Fig. 111.—Section and Plan of Johnson Kiln.

shown in Fig. 111. When slurry was employed with this type of kiln, the somewhat thin slurry was run on to the floor of the flue. In such cases the flue was of much greater length than when briquettes of material prepared on the dry process were burnt in this form of kiln. As usually employed the kiln was intermittent in operation, but at certain works on the Continent it was worked continuously, duplicate flues being employed, so that the dry raw material could be fed from one of them together with fuel, while the gases passed over the wet material contained in the other. The Batchelor kiln also has drying chambers in which the kiln gases are employed. In this type the drying flats are arranged one above the other, and consequently a saving in space results. The kiln gases pass in a zigzag fashion over the drying floors

and thence to the chimney, and openings are provided in the wall of the burning chamber by means of which the raw material can be loaded into the kiln from all of the floors.

The Hoffman or ring kiln, shown in plan in Fig. 112, occupies a position between the intermittent and the continuous kilns, as its chambers may be regarded as a series of intermittent kilns; while, as a whole, it must be considered as a continuous kiln. The burning chamber is in the form of an endless canal or tunnel provided with a number of doors or openings in the outer wall. These openings are provided for the loading of the material into the kiln, and their number is regulated by considerations of convenience in working. The space between one opening and the next forms one chamber, so that for each chamber there is one door; while

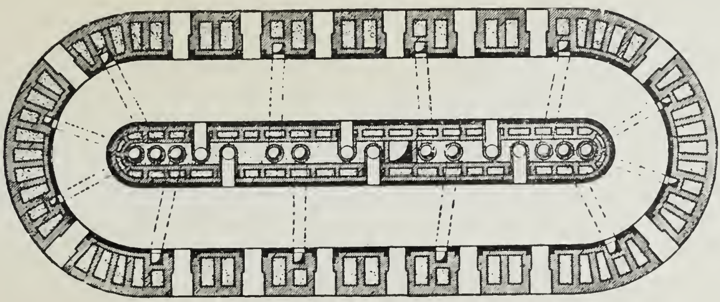

FIG. 112.—Plan of Ring Kiln.

the chambers are separated one from another by paper, or occasionally, sheet-iron dampers extending across the section of the burning canal. A number of openings are provided in the vault of the kiln, by means of which coal is introduced, and the chamber is fired. The air necessary for combustion enters the kiln by means of the doors behind the chamber being fired, and passing over the hot, burnt material contained in these chambers it enters the chamber under fire. The gases from this chamber pass by means of a flue to those which have been loaded, and thence to the chimney. As soon as one chamber is burnt off, the heat contained in the burnt material is utilised for heating the air necessary for the combustion of the coal employed for burning off the next chamber, and so on.

The construction of such a kiln for burning Portland cement mixtures must be extremely strong to withstand the strains consequent upon the high temperatures employed; furthermore, the fire-bricks used for lining the kiln must be of the best quality, possessing high mechanical strength and great resistance to the fluxing action of the alkaline clinker.

The number of chambers recommended by one of the leading firms of constructors for kilns burning Portland cement is twenty, each 16 feet in length, and this will give an output of 30 to 35 tons of clinker per day. Owing to the shrinkage which takes place in the burning of lime and cement, a space is left between the burnt goods and the crown of the canal, and the air would, therefore, pass over the top instead of through the mass of the material contained in the kiln. To prevent this, arches are constructed at intervals,

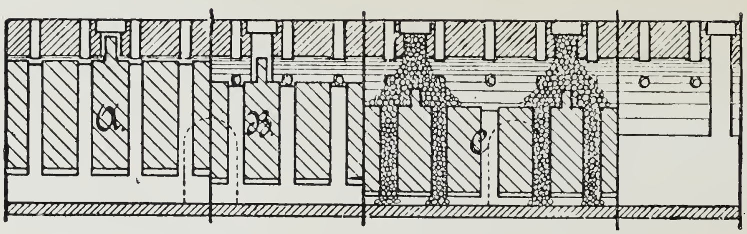

Fig. 113.—Arrangement for filling Chambers of Ring Kiln.

which reach down a certain distance, thus reducing the sectional area of the canal. These arches are, however, a source of expense, owing to their frequently needing repairs, and a more satisfactory arrangement is obtained by filling in a further quantity of the raw mixture by means of slits arranged in the vault of the chamber. This arrangement is illustrated diagrammatically in Fig. 113, where *a* is a chamber freshly filled, *b* is one which has been partly burned, and *c* one which contains the fully clinkered mass with the additional material fed in. The use of the old cone valves for regulating the flow of the gases is also a source of annoyance, which is most pronounced in cement kilns owing to their increased draught which removes the sand from their seatings.

The use of iron pipes for making connection between the smoke outlet from the burning chamber and the flue in place

of these valves is advantageous, for by this means leakage (therefore waste of fuel) can be absolutely prevented; the connecting pipes being removed, and the holes covered with iron caps when it is desired to interrupt the connection. At the points where the burning canal bends round, the middle wall of the kiln is lengthened, and the smoke outlets are arranged entirely in the outer wall, for the fire when turning the corner, so to say, has the tendency to take the shortest course, with the result that the burning would be less uniform, in the chambers so situated, unless such devices were employed. A section of a kiln provided with these iron pipes is shown in Fig. 114.

The chimney is usually situated midway between the ends of the kiln, or in its centre, if circular in plan, but a single

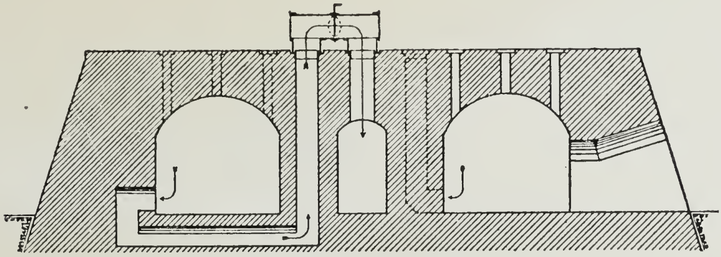

Fig. 114.—Section of Ring Kiln with Iron Connecting-Pipes.

chimney can be employed for two kilns, in which case they are connected with it by means of underground flues. The consumption of fuel with this form of kiln is from 16 to 20 per cent. of the weight of the clinker produced. The consumption is largely effected by the way the fuel is introduced, the proper way being to add the coal in uniform quantities at regular intervals.

In England these kilns have not been very successful when employed for burning cement mixtures, but on the Continent there are several firms who are strong supporters of them. The labour costs, which would appear to be much greater with this form of kiln than with the vertical shaft kiln, have by no means counterbalanced its other advantages.

For smaller outputs, 30 tons per day, the cost of erection of a complete ring kiln renders it an uneconomical plant. In

such cases, and especially where an increased demand may reasonably be anticipated, a partial ring kiln is often erected. This is essentially one-half of a ring kiln with a chimney so dimensioned that it merely requires heightening to make it suitable for the complete kiln. It is semi-continuous in operation and has a grate provided at one end which is used for starting the kiln. After the first chamber is burnt off, the operation is the same as the continuous kiln until the burning of the last chamber, when if it is required to start another round, the fire on the grate must be started. It will be seen that in one round enough clinker can be produced to keep a small mill running for some time, and when a further quantity is required the kiln is restarted.

While in the ring kiln, the fire moves forward relatively to the burning chamber and the material to be burned, in the shaft kiln, the fire remains stationary and the material moves.

The Schneider, Hauenschild, and Stein kilns are plain cylindrical shafts provided with chimneys. The first mentioned has been largely employed in this country and has proved itself satisfactory in all respects. It consists of a cylindrical brick shaft lined with fire-brick and the briquettes and fuel are fed in in layers at the top, the fully burned clinker being abstracted at the bottom of the shaft. By means of a truncated conical hood the shaft is connected to the chimney either direct or by means of a flue into which a number of such kilns discharge their gases. An essential point with this kiln is the employment of a layer of crushed raw material as a medium for protecting the lining of the kiln; a form of protection which is much more satisfactory from a theoretical than a practical standpoint. Another system of operating this kiln is by feeding it with briquettes formed of raw mixture and coke breeze, the kilns being worked under forced draught, by which means the output per kiln is increased and the burning is rendered even more uniform, while at the same time there is a considerable saving due to the difference in cost between coke breeze and broken coke. The Hauenschild differs from the Schneider kiln in the means adopted for preventing the clinker hanging on to

the walls of the burning chamber. To this end, instead of a packing of raw material being used, the kiln walls are made as thin as possible. In practice, the walls are formed of fire-brick with a sheet-iron casing, and around this, at a distance of some 30 inches, is a wall of reinforced concrete. The cylindrical shaft is closed at the top by means of a cast-iron plate and the kiln is connected with a chimney by means of a flue arranged below this cover. The grate, situated at the bottom of the kiln, is a form of step grate in the form of a pyramid and the drawing eyes are provided at the four sides. In the later installations the kilns are operated with

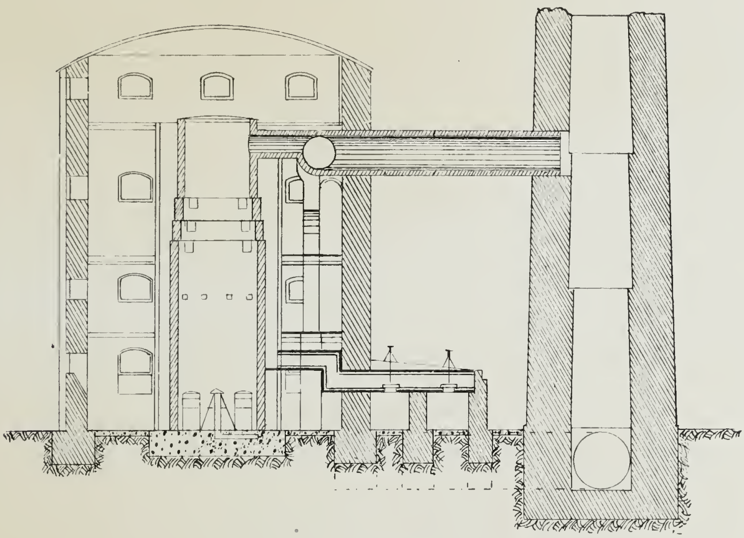

FIG. 115.—Hauenschild Kiln.

forced draught which in all shaft kilns leads to an increase in output and reduction of fuel costs. The inventor recommends the use of spherical or cylindrical briquettes of raw material weighing about 3 lbs. each—these are loaded in together with coke. The output for a kiln 3 metres in diameter is given by Schoch as 22 tons per day.

As an additional means for preventing the clinker adhering to the kiln walls, the addition of powdered lime, strewn round the charge, is sometimes made use of.

The Stein kiln is a form of shaft kiln which has been employed very largely for burning raw mixtures made from

blast furnace slag and limestone. It depends for the prevention of the arching, or hanging up of the clinker, upon the rapid cooling of the walls and neutrality of the material from which they are constructed. The kiln is formed of a number of cast-iron annular sections each 18 inches high, cast with channels on the outer side. These rings are placed one above the other, and the channels extending from top to bottom of the shell have a chimney-like action; moreover the radiating surface is largely increased by the projections, which also add to the strength of the rings. The cylinder is 6 feet 6 inches to 8 feet in diameter and 23 to 30 feet high, and is supported on short columns. At the top it is surmounted with an iron cover in the form of a truncated cone supporting the chimney and provided with four openings for charging. The output of a kiln of the largest size mentioned is 15 tons per day. The expense of replacing burnt-out rings is infrequent and then not heavy.

A number of firms construct shaft kilns suitable for the burning of Portland cement; in general, they are in the form of a cylinder or taper slightly toward the top, and when of this form they are more particularly suited for the clinkering of material which forms somewhat soft and friable briquettes. Each firm has some particular system of preventing the clinker fusing on to the walls of the kiln or of rendering it easily removable, points having a very considerable effect on the labour and repair cost. Another class of continuous kiln is that in which the preheating zone is separated from the burning zone more or less sharply by the conformation of the kiln. This class merges into the one previously described, but nevertheless the difference in construction is sufficiently pronounced to warrant the division.

The Dietzsch kiln is the predecessor of a number of kilns, none of which have so eclipsed their prototype as to secure its relegation from the field of activity into that of historic retirement. The principle upon which it is designed is to secure fuel economy by employing the hot clinker to heat the incoming air, which passes to the fire zone, and to utilise the heat contained in the gases of combustion to heat the raw material, while so arranging the preheating zone as to

prevent the whole weight of material which is being dried from bearing upon the semi-fused clinker. The effect of the long column of material being warmed up, in certain shaft kilns, is to press the semi-fused clinker outward and to cause the mass to hang up in a solid block, adhering to the walls of the clinkering zone. Dietzsch, to prevent this, arranged the preheating zone out of the line of the burning zone, the weight of the material being borne by the kiln structure.

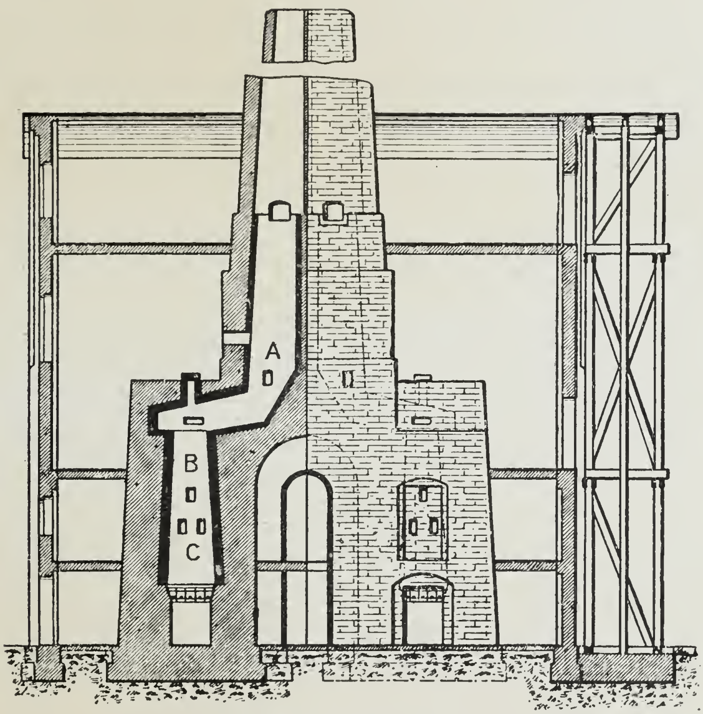

Fig. 116.—Dietzsch Kiln.

In Fig. 116 a modern form of the Dietzsch kiln is shown. It consists of a clinkering zone B above the cooling zone C both oval in section. Above and behind is the preheating zone A inclined at its bottom to the burning zone. The raw materials in half bricks are fed into the preheater by means of the loading eye. The fuel is fed in by means of two doors one on each of the smaller sides of the oval clinkering zone. Other openings are provided in the preheater and burning shaft, the object of which is to facilitate the operation of the

kiln by enabling the mass of raw material to be drawn into the clinkering zone and for knocking down any masses of clinker which may hang up.

When the kiln is in operation, clinker is withdrawn at intervals of two or three hours, a further quantity of fuel being charged into the kiln and the space filled up by dragging a fresh charge of raw material from the preheater, a light layer of fuel then being shovelled in. The quantity of fuel employed varies with materials of different fusibilities, and of course depends upon the skill of the burner and the calorific value of the fuel; with a coal of average quality, it is from 17 to 20 per cent. of the weight of clinker produced. The output is from 10 to 12 tons per kiln.

As a rule the kilns are constructed in pairs as shown in the sketch, the cost per kiln working out less when this system is employed. In the original design the connection between the clinkering and preheating zone was made by means of a passage at right angles to these two chambers. At present, however, the practice is to incline the floor of this passage, an arrangement which facilitates the descent of the preheated briquettes into the clinkering zone. The burning zone is widened out towards its lower end, the object being to aid the descent of the clinker. At the burning zone it is now the custom to provide an annular air space behind the fire-brick lining through which a current of air passes, cooling the lining, thus tending to prevent the clinker fusing on the walls. For a similar object a number of jets are sometimes provided by means of which air can enter the kiln at the burning zone.

The Aalborg kiln has been extensively employed throughout the world for burning Portland cement. It is an improvement on the Schöfer kiln and in principle follows the Dietzsch. The design, however, differs considerably from the latter, and principally in that the preheating zone is arranged directly above the burning zone, an arrangement which leads to a saving in labour. Its form can be seen from Fig. 117. The raw material is fed in at A and descending the preheater it comes into the constricted clinkering zone and then passes into the cooler, ultimately to be drawn as

fully burnt clinker. The coal is fed in by means of a number of holes provided with caps and arranged round the kiln. The coal consumption of the kiln is given as being 13 per cent. and the output is from 12 to 14 tons per day.

The "R" kiln is also similar in principle to the Dietzsch. It is shown in Fig. 118, and consists of a cooling and clinkering zone, surmounted by two chambers for preheating the briquettes, the whole being covered by a conical chimney. Between the two preheating chambers there is a passage, the floor of which is perforated with a number of holes provided with covers. Through these holes the fuel—small coal—is introduced. In operation, this kiln is similar to the one previously described. The output of the kiln is 18 tons per day, and the fuel consumption with average raw materials and coal is about 16 lbs. per 100 lbs. of clinker produced. These kilns are arranged in groups, and the kiln house surrounding them is usually a brick-built structure with four floors besides the ground floor, the top being the charging floor, the next the firing floor, and the two following are provided so as to permit of convenient access to the clinkering and cooling zones, which are exceptionally large, the clinker taking four days in its descent, while the clinker is withdrawn on the ground floor. The openings in the kiln shaft are provided on the first and second stories for aiding the descent of the clinker and for breaking up large lumps by means of bars.

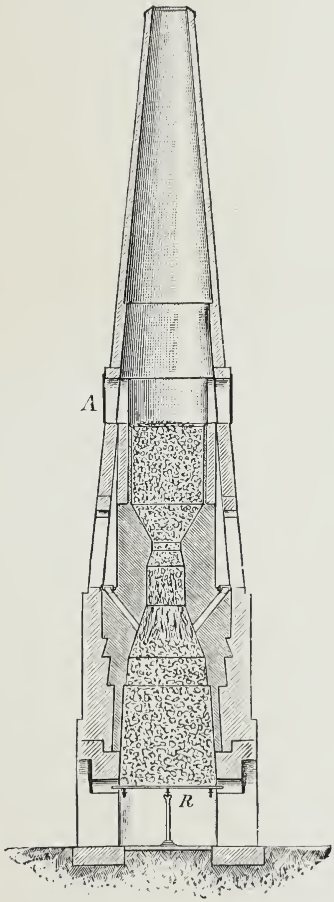

FIG. 117.—The Aalborg Kiln.

The modern tendency is towards the displacement of

chimneys in favour of fans, the process of combustion taking place under the effect of forced or induced draught. By means of a fan it is possible to obtain a current of air more rapid than can be obtained with a chimney unless it is of excessive height. Moreover, beyond a certain limit it is cheaper to instal a fan employing only a short stack than to erect a tall chimney. In nearly all cases the first cost is actually lower, but the cost of upkeep may counterbalance the saving consequent upon the installation of a fan. The precise point at which the fan exceeds the chimney is a matter of discussion, but it will almost certainly occur in the future that the very short stack will be prohibited by law, as by its means the products of combustion are sent into the air at an elevation which is so low as to cause inconvenience to the neighbourhood. As applied to kilns there can be no doubt but that the fan is best employed when delivering air to the combustion zone, and not in extracting the products of combustion. The economy consequent on the use of forced draught generally is due to the more perfect combustion thus obtained, and the localisation of the heat leading to higher temperatures at the point of combustion, and a steeper temperature gradient conducing to a more rapid transference of heat. In practice the fan has had a considerable effect in increasing the output of the kilns and in reducing the fuel consumption. Now a number of firms are employing them with Schneider and other shaft

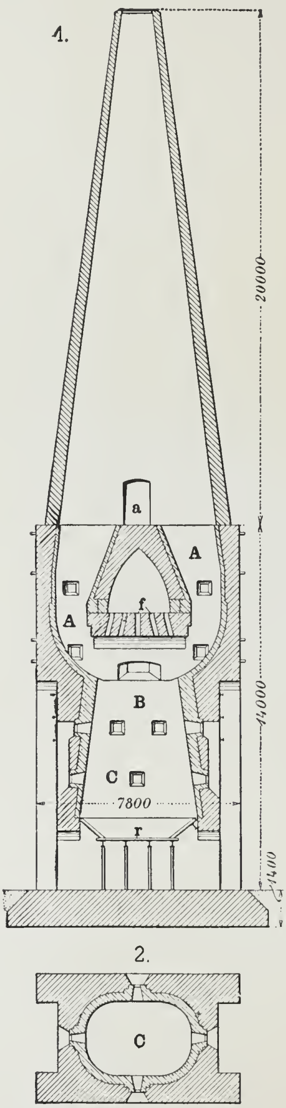

Fig. 118.—Section and Plan of "R" Kiln.

kilns, such as, for example, the Stein and Hauenschild. In such cases the air is led from the fan and is delivered into the kiln at a short distance from the bottom of the cooling zone, and is introduced by means of nozzles formed in the brick lining. With the Dietzsch kiln the pit below the fire bars is, as a rule, provided with a door, and the air is driven into this closed chamber passing thence to the burning zone.

The higher temperatures obtainable with forced draught have led to considerable inconvenience following upon experiments, owing to the fact that the clinker has been fused into a solid lump. No such difficulty is, however, experienced when the fuel is properly disposed and is present in smaller quantity.

CHAPTER II

ROTARY KILNS

The rotary kiln in which by far the greater proportion of Portland cement manufactured at the present day is clinkered is an inclined rotary tube, into one end of which the raw mixture is fed, while at the opposite end the fuel, together with the air necessary for its combustion, is introduced. In its passage through the tube, under the influence of the heat, the water, carbon dioxide, and, to a large extent, the sulphuric anhydride, is expelled from the raw materials and the temperature is raised until they are brought into a state of incipient fusion, by which time it has traversed the length of the kiln and is discharged fully clinkered at its lower end. Rotating furnaces are used in certain other industries, notably in the alkali trade for the calcination of "black ash," and in the iron trade for "puddling" iron, but such furnaces bear no resemblance to the rotary kiln as employed in the cement industry.

Although the use of rotatory furnaces for burning Portland cement was suggested in a more or less lucid manner some thirty years ago, the process being patented by Crampton in 1877, we do not find any instance of practical application until after Ransome had patented his arrangement of the necessary plant in 1885. It would appear that this engineer, to whom the credit of the invention of the rotary kiln is given, lost a considerable sum in his endeavours to get this invention taken up. His kiln, an inclined rotating cylinder 25 feet long and 5 feet in diameter, lined with fire-bricks, every fourth row being set edgewise, and thus forming a projecting fin or ledge extending the whole length of the kiln, was fired with producer gas. The raw mixture was dried, ground, and introduced into the kiln at its upper end; the gas from the producer was passed

into the kiln at its lower end. One of the advantages claimed for this system of producing cement was the saving in power in grinding due to the fine state of division of the clinker. Actually the clinker produced by the rotary at the present day is in the form of small lumps which are extremely hard to grind, requiring an expenditure of power one-half as great again as does the shaft kiln product. The cost of burning and of the lining of the kiln, together with the uncertainty of its operation, combined to make failures of these early attempts. The dimensions of the largest Ransome kiln erected in this country was 26 feet in length and 5 feet in diameter.

The next practical development of the rotary kiln was in the United States, where kilns 60 feet in length and fired with crude oil were erected. The cost of production was, however, excessive, and it was not until Hurry and Seaman applied coal dust as fuel that the rotary promised to seriously enter the field of cement manufacture. In Europe, the first of the newer type of kilns was erected by Carl von Forell at Lollar in 1900 for the production of Portland cement from slag and limestone. With his plant he incorporated a drying drum which utilised the waste heat contained in the flue gases. The result of his pioneer work was the formation of the first European firm specialising in the construction of rotary kilns : the Brenn-Oefen Bauanstalt, in Hamburg.

The means employed by Hurry and Seaman for the introduction of the powdered fuel differs essentially from that subsequently developed, in that they employ compressed air for injecting the fuel and inducing a subsidiary current of air by an arrangement of nozzles on the injector principle.

In shape, the rotary kiln as originally designed was a plain cylinder, and the majority of those in use at the present day are of this form. The ratio of length to diameter has changed considerably from that adopted by Ransome, whose kilns were 26 feet long and 5 feet in diameter. Kilns 60 to 80 feet in length have long been used, but it may be said that the minimum length favoured at the present day is 100 feet; even for dry process plants, while the general tendency is toward a length of 125 feet, and a number of even greater

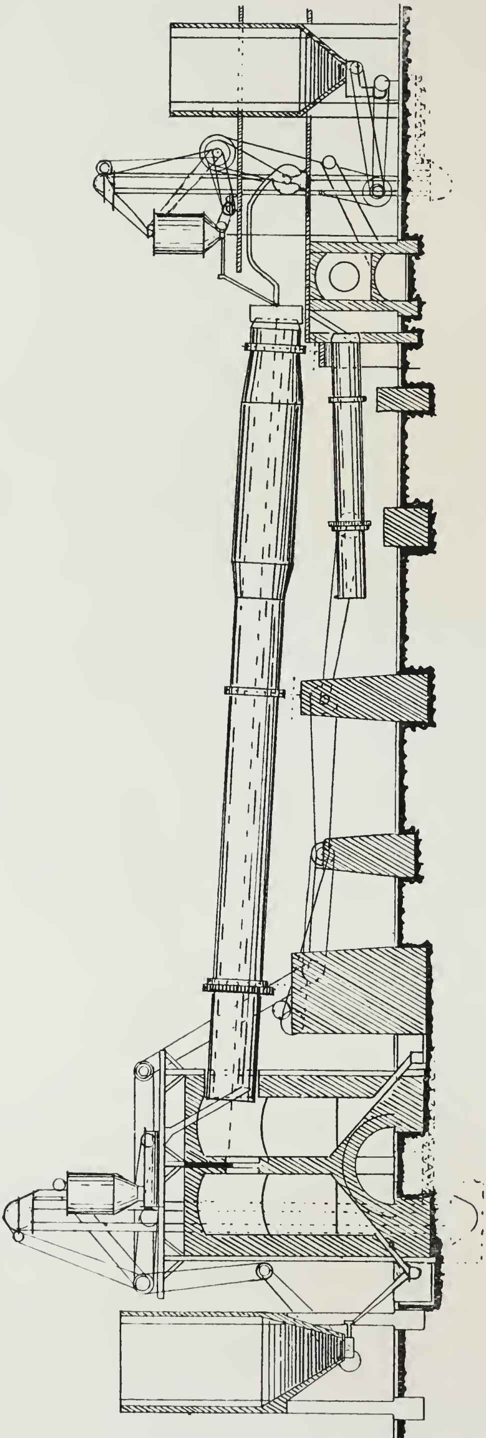

Fig. 119.—General Arrangement of Rotary Kiln Plant with Coal Dryer behind Cooler.

length, up to 160 feet, have been installed. The diameter of the shell of kilns up to 125 feet in length is, as a rule, 6 feet 6 inches, although in America kilns of this length have been constructed having a diameter of up to 8 feet. With the longest kilns the diameter of 9 feet 9 inches is not exceeded.

A variation from the cylindrical form is exhibited in the kilns manufactured by the Allis Chalmers Company, who reduce the diameter of the end where the kiln enters the flue; the end being gradually tapered and thus assuming a conical form. The object of such a formation is obscure; the reduction in cross sectional area must have a tendency to reduce the draught without materially affecting the velocity of the gases in the hottest portion of the kiln. A number of kilns were erected some years ago which were formed of two sections of different

diameters joined by a conical connecting piece. From the statements of the engineer who built these kilns, it appears that his only object was the utilisation of two 30-foot kilns of different diameters, which would have otherwise been scrapped. The system has, however, been adopted by certain firms as a feature in kilns of their construction. It has been stated by the manufacturers of these kilns that the gases passing through the tube become reduced in volume as they travel toward the chimney in consequence of their fall in temperature, which is certainly the case notwithstanding the fact that CO_2 is given off from the raw mix. A modification of this design has now come into extended use on the Continent; the diameter of the kiln being increased from 2 metres to $2\frac{1}{2}$ metres for the first 10 to 12 metres of its length. A kiln of this form is shown diagrammatically in Fig. 119. It will be noticed that at the discharge end it is again contracted to the smaller diameter, in which feature it differs from the type previously described. In the particular kiln illustrated the diameter is gradually increased to its maximum, and then as gradually reduced, the connecting pieces being funnel shaped. In the design adopted by another firm the connection is made by means of pressed steel rings, or by means of two angle rings forming a Z section.

It has been conclusively shown that this form of kiln gives a greater output with increased economy of fuel; the effect of widening the clinkering zone being greater in both these respects than that obtained by lengthening the kilns. The other advantages possessed by this form is the reduced tendency to "ring up" by the fusion of the coal ash with the clinker, the mass thus formed adhering to the lining; the increased speed with which the material passes over the surface of the kiln and the increased area over which the weight is spread being the cause. The increased area of heated lining, and the greater surface exposed by the material in the clinkering zone, are factors very largely affecting the output of this form of kiln.

As at present constructed the body of the kiln in the majority of cases is formed of boiler plate riveted to butt

straps. The thickness of the plating is, as a rule, $\frac{1}{2}$ inch, and the butt straps are made of $\frac{5}{8}$-inch plate riveted, in the case of the circumferential straps, by four rows of rivets $\frac{13}{16}$ inch in diameter. In the case of the Edison kilns the tube is built up from a number of flanged cast-iron sections bolted together, but this system has not been copied in any other works. To obtain the same strength the walls of the kiln must be made thicker when cast iron is employed, and it is doubtless on account of the weakness of the material employed in the case cited that the number of roller paths is so great. Ten of these paths or tyres are used on these

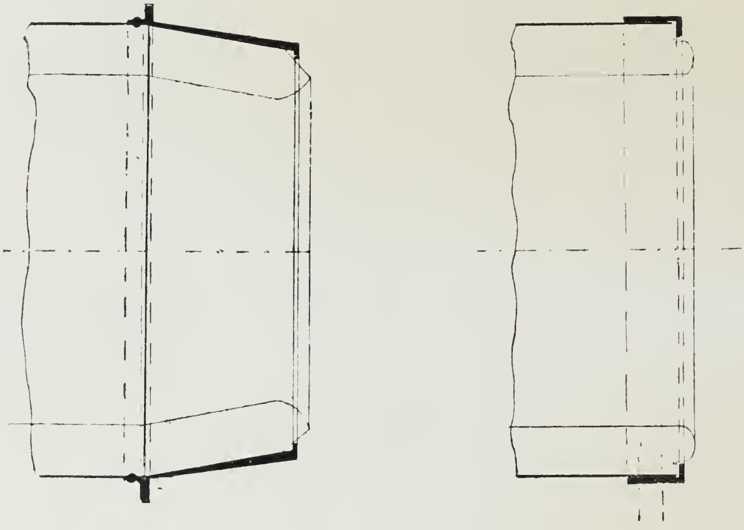

Fig. 120.—Sections of Discharge Ends of Rotary Kilns.

kilns, which are 150 feet in length, while in the European kilns of the same length made from steel plate not more than four such rings are employed. A system of construction has been patented by Messrs Newell in which the tube is built up from a number of sections of welded steel tube to which machined angle rings forming flanges are riveted. The faces of these rings are recessed so as to fit one another and the flanges bolted together with machined bolts. Means must be provided to take up the end-thrust of the lining. Different manufacturers provide different means to this end. Frequently it is in the form of a tapered end in cast iron, bolted

to an angle ring riveted to the steel shell, as shown at *a* in Fig. 120. This design is theoretically better than that shown at *b* in the same figure, which, as will be seen, is in the form of an angle ring of cast iron riveted to the shell. Occasionally the angle ring is formed of mild steel.

This portion of the kiln is always lined with firebrick, the first course being bull-nosed, and, projecting beyond the

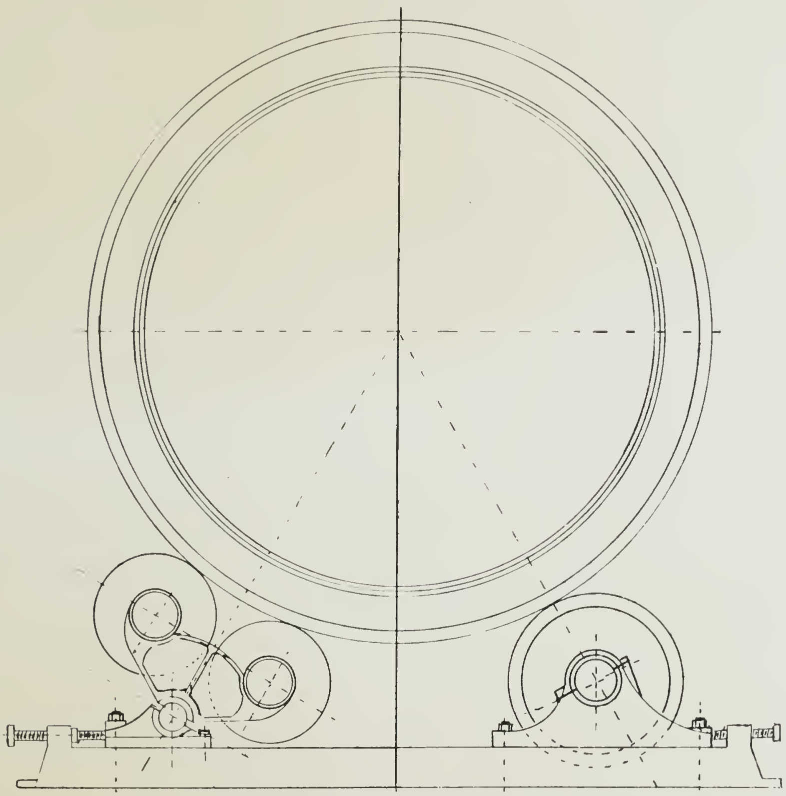

Fig. 121.—Forms of Kiln Bearings.
a, Rocker Bearing for Kiln. *b*, Plain Roller Bearing.

flange, protects it from damage by the passage of the hot clinker.

The roller paths are secured to the shell either by riveting to them direct or by riveting the paths to bridge pieces of mild steel supported on blocks, the bridge and block being riveted to the shell. This latter system is adapted to give a certain amount of play to the ring, thus making an elastic

connection. The rings themselves are of tough cast iron or steel, usually the latter, and of either rectangular or I section.

Each ring bears upon rollers secured to a sole plate. For some time it was the custom to employ four rollers arranged in couples for the support of each ring. The rollers in such

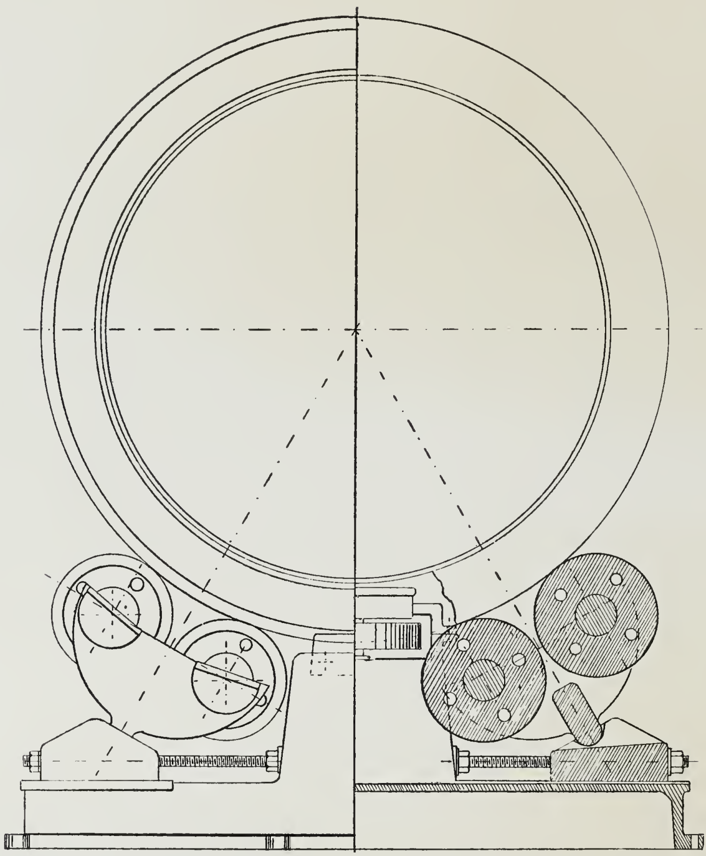

Fig. 122.—Kiln Bearings (portion of Ring cut away to show Check Roll).

cases are secured to rockers each of which is supported by means of a journal in adjustable bearings. The arrangement of this system of support is illustrated in Fig. 121, *a*. Recently the use of two rollers for each ring has become general, this arrangement possessing the advantage of increased simplicity and being found in practice at least equal to that previously described in other respects (see *b*, Fig. 121).

Another type of kiln bearing is shown in Fig. 122. So far as the principle is concerned, the system of supporting the kiln is the same as that shown above, but the design is somewhat different. In this case the rolls are set by means of long bolts in tension from the centre of the bedplate. The construction is also extremely massive, and it may be noted that a check block is provided to prevent the kiln running up, as sometimes happens. As a rule no means are provided to prevent this occurring. Should the kiln actually run off the rolls considerable damage may be done, and in any case the stoppage in consequence would be an expensive matter. With the ordinary type of kiln base such an accident should never occur with proper attention, but the provision of a stop block or of an automatic cut-out is obviously an advantage. While dealing with kiln bearings it may be mentioned that the Continental practice is to journal the rollers in cast-iron boxes with a brass bush pinned in, whereas in America split bearings are more usual.

It is of the utmost importance that the rollers should be kept properly adjusted, for if this is not attended to and the kiln gets out of line, sooner or later extensive repairs will have to be carried out as the rivet joints will be racked and the rivets sheared or the holes made oval. For another reason also the kiln rollers should be kept properly adjusted, for in this way the running up of the kiln can be avoided and undue pressure on the check roll relieved.

The thrust of the kiln is taken up by means of rollers bearing on one of the roller paths, its axis being at right angles to the horizon.

The kiln is rotated by means of a pinion engaging with a split circular rack, which is either rigidly secured to the tyre or is connected with it by means of bridge pieces. Another system of connecting the rack to the shell is by means of a number of strips of steel plate arranged tangentially to the periphery of the kiln. The rack is usually fixed at equal distances from the two ends, but occasionally, and more particularly in the shorter kilns, it is secured about one-fourth the length of the kiln from the inlet or outlet end.

The pinion engaging with the circular rack is driven

through suitable reduction gearing. The reduction is arranged in three steps, the first or last reduction being by means of bevel wheels when a belt drive from the line shaft-

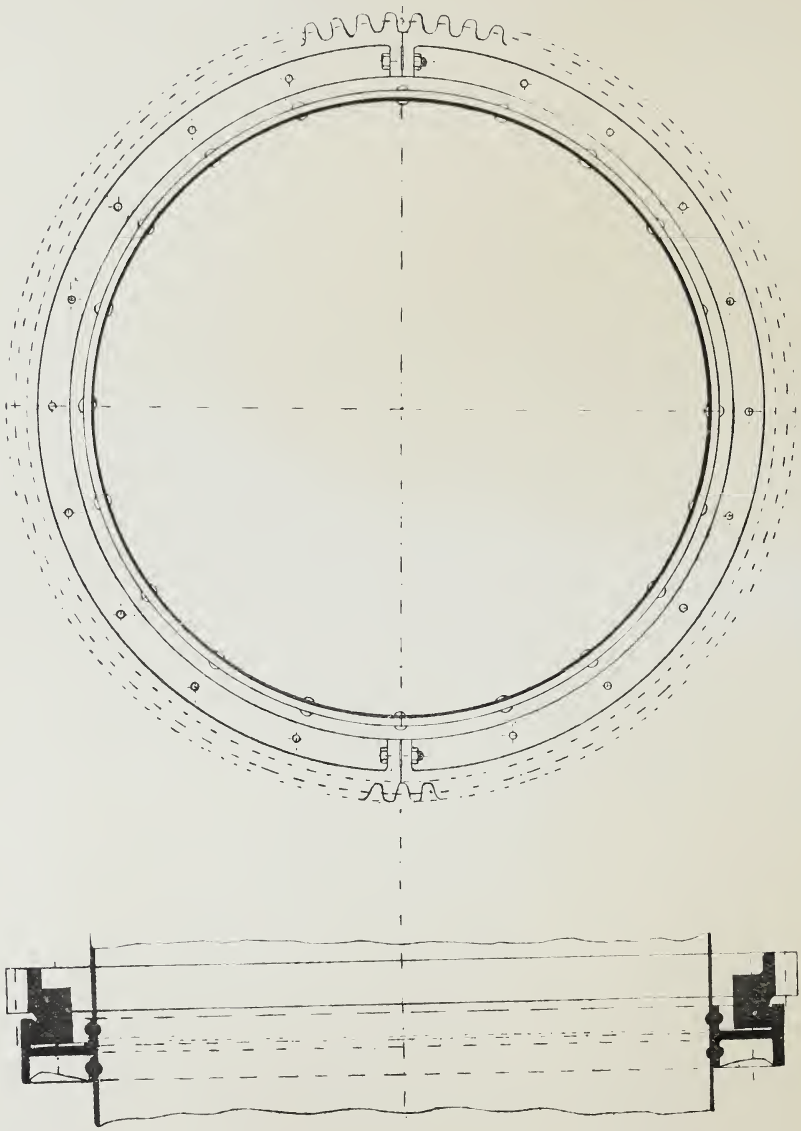

Fig. 123.—Driving Ring secured to Tyre Ring.

ing or a motor is employed. When, however, a direct drive from a motor is adopted the reduction is by means of a train of spur wheels.

The wheels employed should be of the highest grade,

machine moulded, the pinions at least being of steel. The slow moving shaft should also be amply proportioned, as it has to transmit normally about 8 to 10 horse-power at about six revolutions per minute.

The lining of the kiln is a point of very great importance in regard to economy in operation. If unsuitable material is employed an enormous amount of money may be wasted

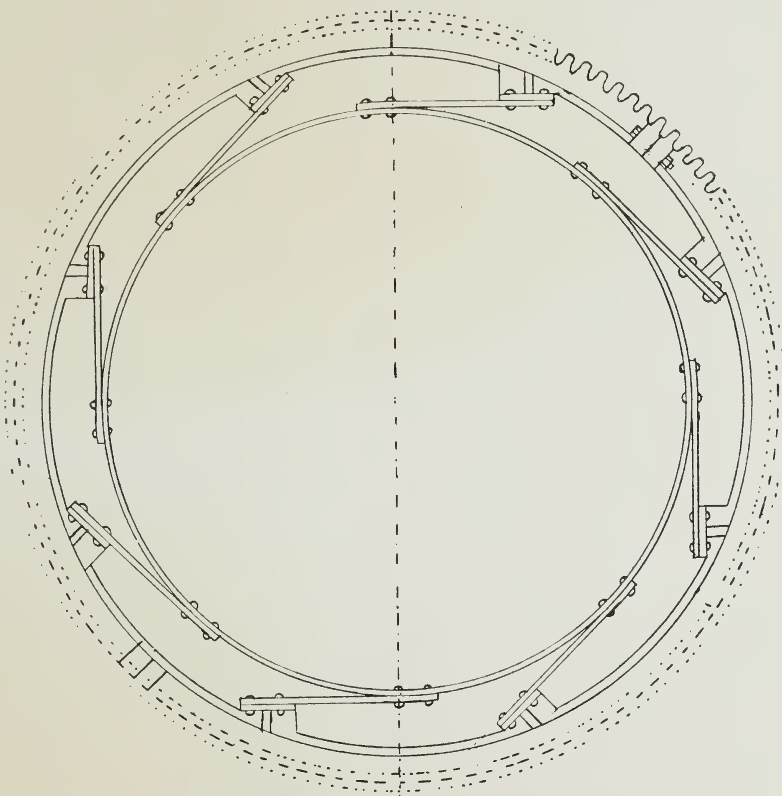

FIG. 124.—Driving Ring secured to Shell by Tangent Strips.

in frequent relinings and by the interruption of the working. Again, by excessive "carefulness" a very large amount may be wasted by employing expensive material where cheaper stuff would do equally well. The section of the kiln where the requirements are most exacting is the first 20 feet, for here the lining has to withstand the highest temperature and the greatest eroding action in consequence of the alkaline clinker being in a semi-molten condition.

The majority of fire-bricks manufactured in this country are of an acid character, being extremely high in silica, while the most suitable are those which are low in silica, and contain a high percentage of alumina, that is when the proportion of silica to alumina approaches the ratio 1 : 1.

The highest class of brick of this type employed in the States has a composition within the limits given by the following figures :—

	Per Cent.	Per Cent.
Silica - - - - -	55·0	50·0
Alumina - - - -	45·0	40·5
Ferric oxide - - - -	3·5	2·0
Lime - - - - -	1·5	0·3
Magnesia - - - -	1·0	trace

Magnesia brick has been employed to a certain extent, but its use has now been given up. Bauxite bricks have also been employed to a limited extent, both in the form of full bricks and as tiles, as a protective surface for the more silicious brick on which they are laid.

Concrete made from clinker and cement is one of the most useful and cheapest linings for the burning zone. With proper treatment a life up to one year can be expected from it.

This system of lining is extensively employed both in this country and on the Continent.

The clinker employed should be hard burnt and preferably fresh from the kiln. Its composition should be normal or a little high in lime. The material should be screened, and, as a rule, the portion passing the half-inch and caught on a quarter-inch riddle is used, being mixed in the proportion of two parts clinker to one and a half parts of cement. The mixing should be well carried out, and the concrete should be somewhat on the dry side. In this state it should be well rammed between the shuttering and the kiln shell, and allowed to harden for twenty-four hours; the shuttering being removed when the mass is set. During the hardening process it is advantageous to have a fire in the kiln, burning on an iron plate, or in a bucket, out of direct contact with the lining.

The composition of the concrete sometimes recommended is in the proportion of two and a half parts of clinker to one of cement, the clinker all passing the quarter-inch riddle.

The cost of relining a kiln in all cases depends largely on the difficulty of removing the old lining, but £1 per lineal foot with a kiln 6 feet 6 inches in diameter, the lining being 9 inches thick, may be regarded as an outside figure for labour. For material mixed in the proportion of two parts clinker to one and a half of cement, the quantities are 10 cwt. of clinker and 6·6 cwt. of cement per lineal foot.

The lining beyond the first 25 feet is usually of the commoner class of fire-brick, and for the last 25 feet ordinary well-burnt stock bricks are frequently employed. A typical example of the arrangement of the lining is: the first 20 feet of 9-inch work in clinker concrete, then 30 feet of 9-inch fire-brick, followed by 30 feet of 4½-inch fire-brick, and the remaining 27 feet in stock brick.

The relining of the burning zone, the first 10 to 12 feet, is the most frequently recurring expense; the upper portion of the lining lasting, with only slight repairs, for at least two or more years. With ordinary care the burning zone will not require relining more than once in nine months, or once in twelve if suitable material has been employed and the work carried out properly. The thing to be most carefully guarded against is interruption in running the kiln and consequent cooling down and reheating. Occasionally red patches may appear—that is the plate gets red hot—at the burning zone, and unless the lining is repaired much damage may be done. This patching is carried out by getting a good heat in the kiln, and ramming the almost fused clinker well into the hole, after which the kiln should be allowed to cool down, the patch being, naturally, at the bottom. Such patches frequently last a considerable time if the lining is not too thin, and they have been put in at a good heat.

It may here be mentioned that the employment of a layer of asbestos behind the fire-brick has been patented and to a certain extent used in practice, but its value is very doubtful,

as the layer must necessarily be so thin as to be of little value in preventing loss of heat, and must also tend to weaken the keying of the lining.

Rotary kilns are always slightly inclined, the pitch being anything from $3\frac{1}{2}$ to 7 per cent. It has been stated that at this latter angle the material moves forward too rapidly and irregularly and that the former angle is best. The speed at which the material moves forward is much more affected by the angular speed of rotation and the diameter of the kiln than by the pitch. By regulating the speed, any rate of travel can be imparted to the material. The inclination most usually adopted in modern installations is 5 per cent. The speed of rotation varies from one revolution in forty seconds to one revolution in two minutes for a kiln about 6 feet 6 inches in diameter; with greater diameters the speed is sometimes less.

In many plants the kilns are arranged so that they may be driven at different speeds. This is done by arranging pulleys of different diameters on the first motion shaft so that one belt may be run on the fast pulley of greater diameter while the other is on the loose pulley of less diameter, or *vice versa*. An alternative to this arrangement is the use of a variable speed gear or of separate motors provided with controllers for each kiln.

The employment of a variable speed drive is to a certain extent advantageous, but the speed at which the kiln should travel is scarcely a matter to be left in the hands of a burner as they are chiefly concerned in getting out good clinker with the minimum of trouble to themselves.

The kiln hood should be provided with a door by means of which access may be obtained to the kiln; two, or preferably three, sight holes, one being placed at the side of the hood; and the burning attachment. As a rule, it is formed of steel plate and is lined with fire-brick, the use of water-cooled hoods having practically ceased. In the older plants the front of the hood was in brick, and access to the interior of the kiln could only be obtained by knocking out a portion of the brickwork. In the earlier plants also the hoods were fixed, but now they are mounted on wheels, and can thus be

easily run back, giving easy access to the kiln for relining or changing the nozzle.

In many cases the cooler head is also supported from wheels so that it can be run back if required. With them a door is arranged immediately opposite the cooler end to facilitate inspection and the replacement of chute plates. The bottom of the cooler head should be in the form of a hopper and be provided with a slide, so that any clinker collecting here may be easily removed. Connection between the pipes leading to the coal feed and to the drier is made by means of openings in the hood, to which the pipes are bolted.

In the most recently erected works the cooler has been arranged so that its upper end opens into a dust chamber, behind which is placed the coal drying drum. In such cases the cooler head is not made removable, but is a brick structure arranged beneath the burner's platform.

The cooler in most European works is a rotating cylinder, the axis of which is slightly inclined or is horizontal. Most frequently it is a plain tube of steel plate, riveted, and provided at the end where the white hot clinker enters with a cast-iron section, the interior of which is provided with L-shaped scoops. In certain instances this upper section is made of boiler plate and is then lined with cast-iron plates, an air space between them and the shell being left; or it is lined with fire-brick. The cooler is provided with a number of channel irons secured to the shell, which, on the rotation of the drum, lift the clinker and then cause it to fall in the form of a cascade, thus bringing it into intimate contact with the air passing through the cylinder. The coolers are supported by means of two roller paths on rockers or plain rollers, and the rotating motion is imparted by gearing similar to that employed for rotating the kiln. The Smidth cooler is of a different type. It is arranged with its axis horizontal, and it has a cylinder surrounding it for half its length. The clinker passes into the cooler by way of a chute, and passing the length of the inner cylinder, it then travels backward between the drums and is discharged into a hopper and thence to the conveyor. The inner cylinder is lined for half its length with cast-iron plates, between which and the

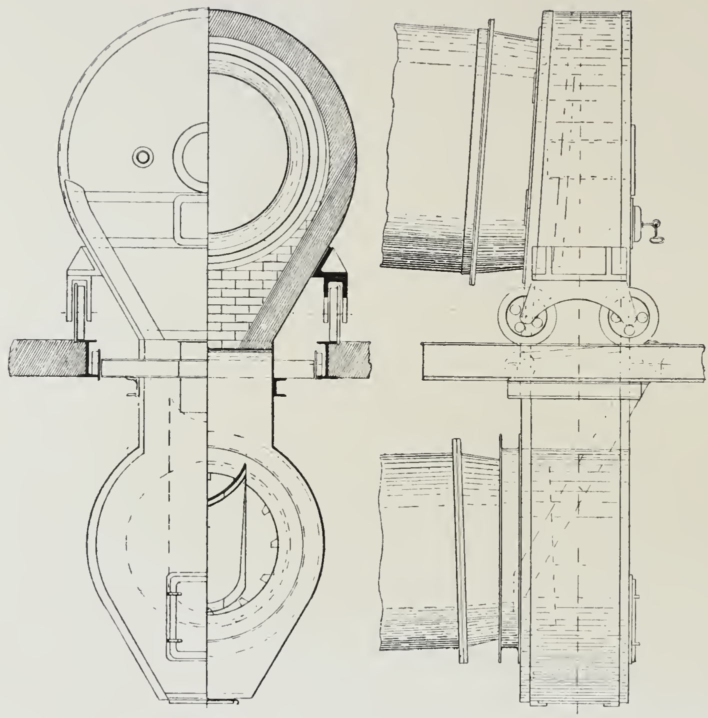

Fig. 125.—Kiln and Cooler Heads arranged on Carriages.

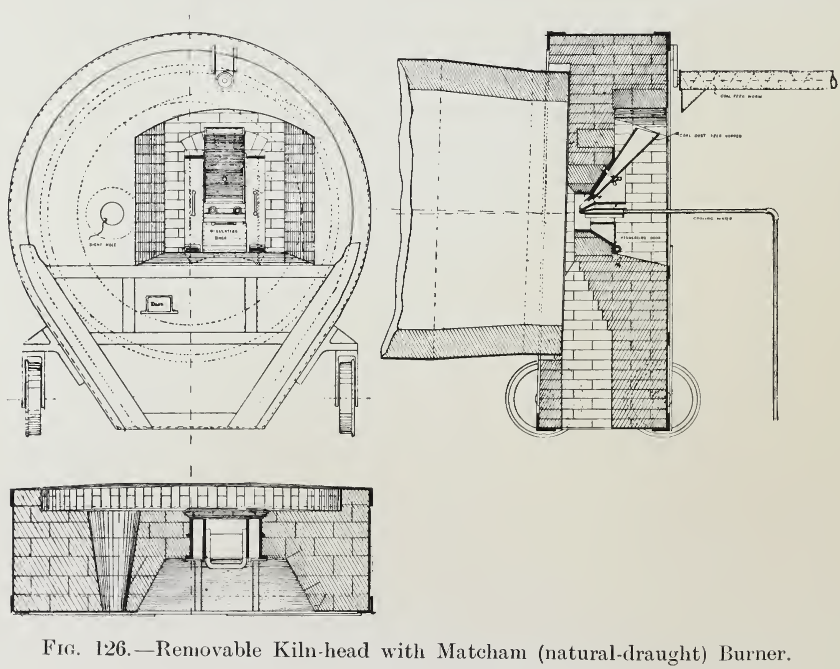

Fig. 126.—Removable Kiln-head with Matcham (natural-draught) Burner.

cooler body is an air space protecting the drum from the action of the heat. With this type of cooler the air is either impelled or drawn over the clinker. The former arrangement is preferred, as in this way the fan employed is subject to much less wear and tear owing to the air set in motion by it being cold and practically free from dust, the hot air and clinker dust doing considerable damage to fans which are employed for drawing the air through coolers. In Fig. 127 a plant is shown in which the kiln is worked under forced draught, the air being driven over the clinker in the cooler into a dust chamber, from which a proportion is used for drying the coal, and a portion is taken by means of the hot air pipe and is used for injecting the coal dust. Coolers

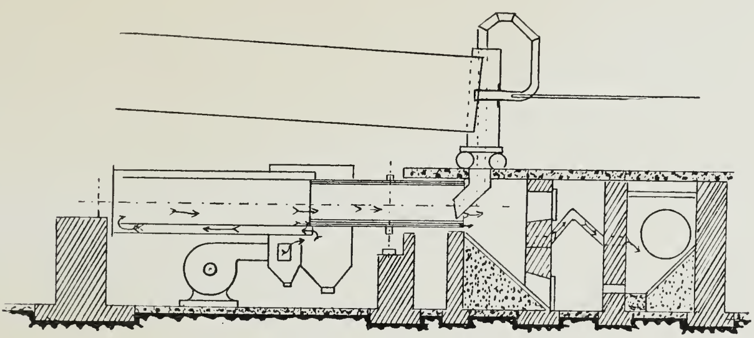

FIG. 127.—Kiln and Cooler, with Forced Draught.

vary in length from 30 to 50 feet, and in diameter from 4 to 5 feet.

The vertical cooler has not been adopted on this side of the Atlantic notwithstanding its popularity in America. As frequently employed, there is a great deal to be said against it. For example, in the older plants, the hot clinker coming from the mouth of the kiln fell into a fire-brick lined pit from which it was taken by means of an elevator to the vertical cooler. The clinker as it descended into the elevator boot was sprinkled with water, the vaporisation of which cooled the clinker and resulted in a loss of heat, a further loss taking place in its passage to the cooler. With coolers of this class arranged immediately below the discharge end of the kiln, such losses are prevented to a large extent; and

that every effort should be made to recover the heat from the hot clinker is rendered apparent on consideration of the fact that an amount of sensible heat equivalent to that obtainable from a weight of coal equal to $3\frac{1}{2}$ per cent. of the weight of clinker is contained in the incandescent mass.

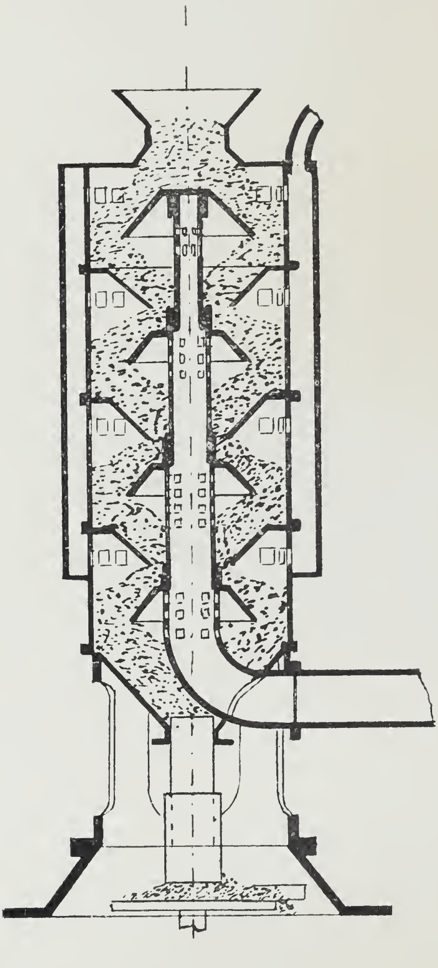

Fig. 128.—Mosser Vertical Cooler.

With the rotary coolers now employed a large proportion of this quantity of heat is lost, but nevertheless a certain amount is usefully employed. For example, the air used to inject the coal, if it is drawn by means of a fan from the cooler, will have a temperature of about 250 deg. Cent.

The tower cooler of the Wm. F. Mosser Company is shown in Fig. 128. It is a double walled cylinder 32 feet in height and 7 feet in diameter. In the centre is the blast pipe perforated at intervals of 5 feet and provided with shields protecting the holes. These shields extend to within 10 inches of the interior drum, and below each is an annular deflector protecting the outlet holes in the inner shell. The air is blown into the cooler by means of a fan, and, travelling through the hot clinker, it is heated and passes into the hollow space between the walls of the tower and by way of a pipe to the coal feed.

With plain cylindrical coolers it is not infrequent to secure to their discharge ends a section perforated with large

holes, the object of which is to divert very large pieces of material, preventing it from dropping on to the conveyor and causing damage by becoming jammed in the elevator boot or blocking the hoppers or feeds. A similar result can be obtained by arranging a grid above the elevator boot into which the clinker is discharged, and this latter arrangement is to be preferred, the cost of repairing such a grid being very small.

In no portion of the burning plant is there such wide variations as in the dimensions and arrangement of the flues and chimney leading away the waste gases. This is one of the most important parts of the plant, and but little attention is paid to it by some engineers. The great volume of the flue gases from each kiln can be appreciated when it is remembered that each kiln is burning not less than one-half ton of coal per hour, and to the quantity of gas thus formed, a further quantity of carbon dioxide, driven off from the mixture, is added; not only so, but the temperature of these gases may be anything from 500 to 750 deg. Cent.—that is much higher than would be found in a boiler flue in a properly managed plant. Constricted flues will, of course, throttle the draught, unless the chimney is extremely high. Furthermore, the kiln gases are laden with dust, and some measures should be adopted for reducing the emission of this dust to a minimum. The only form of dust collector admissible for the treatment of the hot kiln gases is an expansion chamber, the design of which is susceptible of so many variations that only their leading features can be noted. The cubic capacity of a dust chamber for one kiln is not less than 110 cubic metres, and is often more. The chamber itself is divided into two by means of a wall with openings near the bottom; the gases of the kilns are, therefore, caused to pass downward and through the arch into the second chamber from which they are led to the chimney by means of a suitable flue. The bottom of the dust chamber is sloped toward the wall farthest from the kilns, and is so arranged as to form a hopper discharge for the dust which is collected. This dust is either periodically removed, or it is abstracted continuously by means of iron chutes fitted with slides and

opening into a worm conveyor, which takes it to an elevator discharging into the raw meal hopper or to a sump, in the case of a plant operating on slurry, by way of which it is led with fresh slurry to the kilns. The height and diameter of the stack for each kiln depends upon the temperature of the gases with which it deals, and in the most successful plants they are respectively 75 feet from centre line of flue, and 4 feet 6 inches. It is advisable to arrange a door in the dust chamber at the level of the kiln, as by means of it the upper end of the kiln may be inspected without cooling down. Moreover, they form an easy means of sampling the kiln gases. In many cases a number of kilns discharge into a common chimney. Under such circumstances a chimney of corresponding greater diameter and height is required, and the flue must be so arranged that neither kiln affects the draught of the other. Suitable dampers should be provided for adjusting the draught as occasion requires, and for altogether isolating the kilns from the chimney, thus preventing as far as possible too rapid cooling, and consequent injury to the kiln linings.

The mechanism for introducing the raw materials is arranged upon the top of the dust chamber. At one time the use of jets for introducing the slurry under pressure were used and the sizes of the nozzles were varied to alter the feed, but although this system is still in use in certain works where it was originally installed, it must nowadays be regarded as antiquated. In Europe, the practice is to introduce the raw mixture prepared by either the dry or the wet process by means of gravity, using a plain chute. This chute is formed of sheet and is about 10 inches in diameter, being inclined at an angle of not less than 45 deg. to the horizon, and with the dry process it is water cooled.

In the case of slurry, the mix is pumped into a tank which often takes the form of a large cylindrical vessel with stirring gear and overflow, and at the bottom it is provided with an outlet in the form of a cock. By way of this cock the slurry passes into a small receiver fitted with an overflow and adjustable notch. The height of the notch in relation to the surface of the slurry is regulated by means of a lever and wire rope

from the burner's platform; and thus the quantity of slurry passing over it into the feed chute is regulated at will, and with ease, by the burner. In certain instances the slurry is pumped direct into small constant level tanks, and the height of the notch is regulated by means of a hand-wheel; in such cases a man must be kept to vary their height in accordance with instructions given him by the burner by means of signals; or the burner must leave his platform and perform the necessary adjustments. This arrangement is less convenient than the previous, and the absence of a storage tank is to be deprecated because the kilns must stop should the pump stop by accident or design; whereas, with a storage tank above the kilns, sufficient slurry may be available to tide over a short stop, which means that the output of clinker is kept up and the linings of the kilns do not suffer by reason of their cooling. A method of feeding the wet raw materials into the kilns which has recently been adopted by Messrs Smidth differs from those already described by being intermittent instead of continuous. According to this system the slurry is pumped into a small mixing tank from which it runs to a measuring tank which is filled to a certain height; a valve is then opened and the contents pass, by way of the chute, to the kiln, the feed being altered by varying the number of discharges of the measuring tank per hour. In this way the amount of slurry passing into the kilns can be accurately determined, whereas with the notch system it is only estimated, although with sufficient accuracy for practical purposes.

With raw materials prepared by the dry process, European practice shows a remarkable divergence from the American system of introducing the raw mixture into the kilns. According to the process evolved on the other side of the Atlantic, a storage hopper is arranged at the back of the flue and the raw mixture is fed by means of a worm rotatable at various speeds by means of suitable gear into another worm rotating in a water-cooled casing which projects through the flue into the kiln. The materials are thus fed in dry condition into the kiln. This system has been employed at certain works on this side, but another method has been

evolved, which has been adopted to a much greater extent. Small storage bins are arranged upon a platform forming the roof of the flue, and a worm is provided which feeds the material at a variable rate from this hopper into a trough formed of plate. In this trough a square shaft rotates, and to it are secured a number of knives or arms arranged so as to propel the material fed into it. A water pipe perforated with a number of small holes is supported over this trough and in this way the raw mixture is moistened. The amount of water incorporated with the mixture is from 5 to 8 per cent. and is sufficient to make the particles adhere, forming small lumps. These lumps drop from the mixing worm into a chute which leads them to the kiln. The difference between

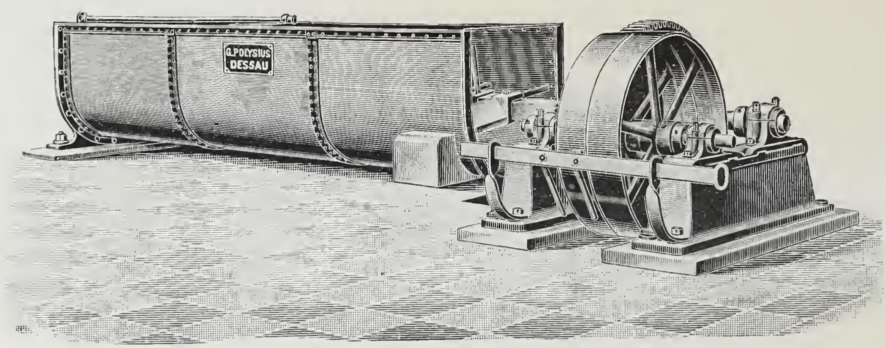

FIG. 129.—Damping Trough.

the two processes is notable, the American consisting in the introduction of the raw mix in a dry condition by means of a worm, while in the European it is introduced in a moist state by means of a chute. At first sight it might seem that the latter system led to a waste of heat, but in fact the loss in this way is almost negligible and it possesses great advantages in that much less dust is blown out of the kiln when the materials are moistened.

The firing of the rotary kiln is usually performed by means of coal dust. After the failure of the Ransome kiln fired with hot producer gas the rotary kiln seemed doomed to failure until the use of a longer kiln fired with oil was perfected by Messrs Hurry and Seaman. The ease with which the oil can be introduced naturally suggests that it would

prove an ideal fuel but the extremely local nature of the supply, though doubtless there are widely distributed and, as yet, untapped sources, has a marked effect in restricting its use. Even in Pennsylvania the use of coal as fuel has extended in spite of the local supply of suitable oil. Moreover, the ease of transport and its small volume compared with the quantity of heat, and more especially of light, obtainable from petroleum, has rendered its use more profitable at places far from its source. Only in Russia and the United States is oil fuel used for firing rotary kilns, and even in the latter only $4\frac{1}{2}$ per cent. of the total output is burnt with this type of fuel, whereas $88\frac{1}{2}$ per cent. is burnt with coal dust and 7 per cent. with natural or producer gas.

In the Hurry and Seaman patents the use of coal dust injected by means of compressed air is covered. According to this system the coal dust is introduced at three zones while the compressed air is introduced by means of a small pipe into a conical nozzle. Atmospheric air and a portion of the coal are drawn in by this injector, the mixture passing into a larger nozzle, where it is mixed with a further proportion of air and coal, and so on through the third. A steam jet has also been used for the introduction of the fuel, but both these methods have been superseded in modern plants and are merely referred to as of historic interest. The more modern plants are arranged with a dust coal hopper for each kiln and a fan for injecting the coal. The quantity of coal dust introduced should be susceptible of variation, in accordance with the amount of heat required for clinkering the materials at any moment. To this end a variable speed gear has to be provided for the coal feed.

The forms of variable speed gear available are fairly numerous, the simplest being a pair of cone pulleys. Stepped cone pulleys are, of course, not admissible, as the variation in speed obtainable from them is not continuous. One cone may be driven from the other one by friction by arranging them a little distance apart and encircling one with a ring, which may be moved along the cone by a guide. Most frequently, however, a belt is employed for

the transmission of the motion, and in such cases it should be made as narrow as possible. To enable a narrow belt to be used, a jockey must be employed to make the belt wrap round as great a surface as possible. A machine of this type is shown in Fig. 130. Another machine, employing a pair of cone pulleys, is of ingenious design. Belts, to which wood blocks, tapered so as to compensate for the conicity, run over each of the cones and between guides

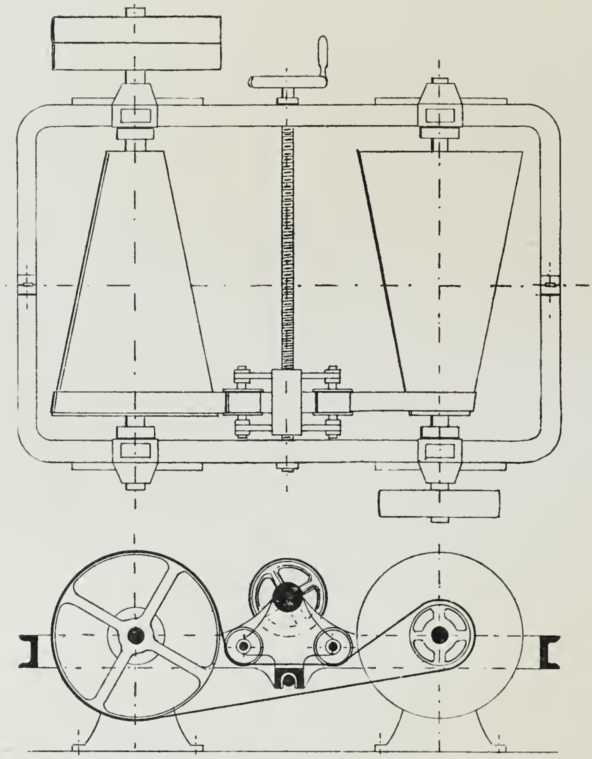

Fig. 130.—Variable Speed Gear, with Cone Pulleys.

secured to a carriage, which can be made to travel across the width of the cones. Over these two belts a plain leather belt passes, transmitting the motion from one pulley to the other. By this means an even (crowned) bearing surface is obtained for the belt.

The variable speed gear most frequently employed is on the lines of the Reeves pulleys. It consists of two pulleys, each formed of a pair of cones and secured

to a spindle, the cones forming each pair being capable of being brought together or moved apart. These two spindles are journalled in bearings arranged in a frame, and a belt, faced with a number of wedge-shaped pieces of wood, passes over the cones which form a pair of expanding pulleys. A pair of levers secured to fulcrums midway between the spindles connect the cones, and by means of a screw operated by a hand-wheel, or similar device, the relative diameter of the driving circles can be varied. This apparatus gives a continuous variation of speed between a maximum and minimum. The illustration, Fig.

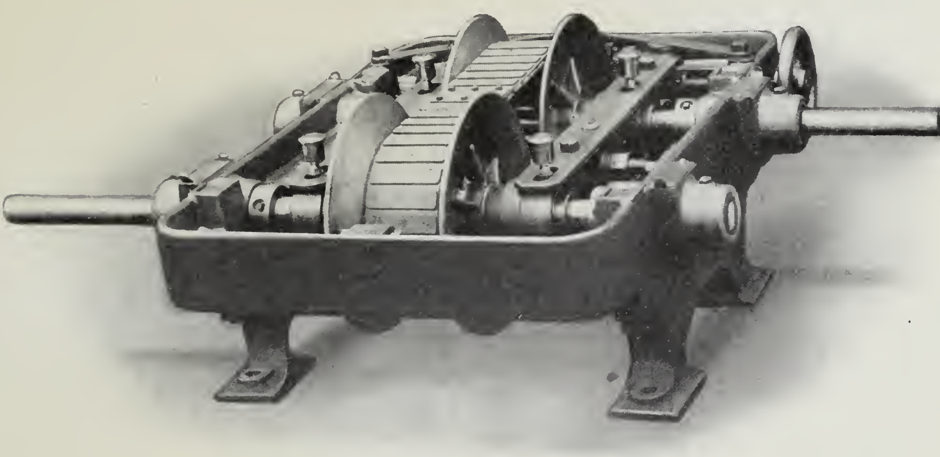

Fig. 131.—Variable Speed Gear, with Expanding Pulley.

131, exhibits the mode of operation and construction of this variable speed gear.

The arrangement adopted by Messrs Smidth for varying the coal feed is shown in Fig. 132. The worm conveyor at the base of the coal hopper is driven by means of a friction disc and wheel, the former being secured to the conveyor shaft, and the latter to a countershaft driven at constant speed. By varying the distance of the wheel from the centre of the disc against which it bears, the speed of rotation of the worm is varied, being increased the nearer the friction wheel is to the centre of the disc. The adjustment of the speed is carried out while running by means of a screw rotated by a hand or

chain wheel; such rotation causing a nut connected by a link to a collar on the friction drum to move to or from the centre of the disc. The pressure between the wheel and disc is kept constant by means of a weighted lever acting upon the worm shaft.

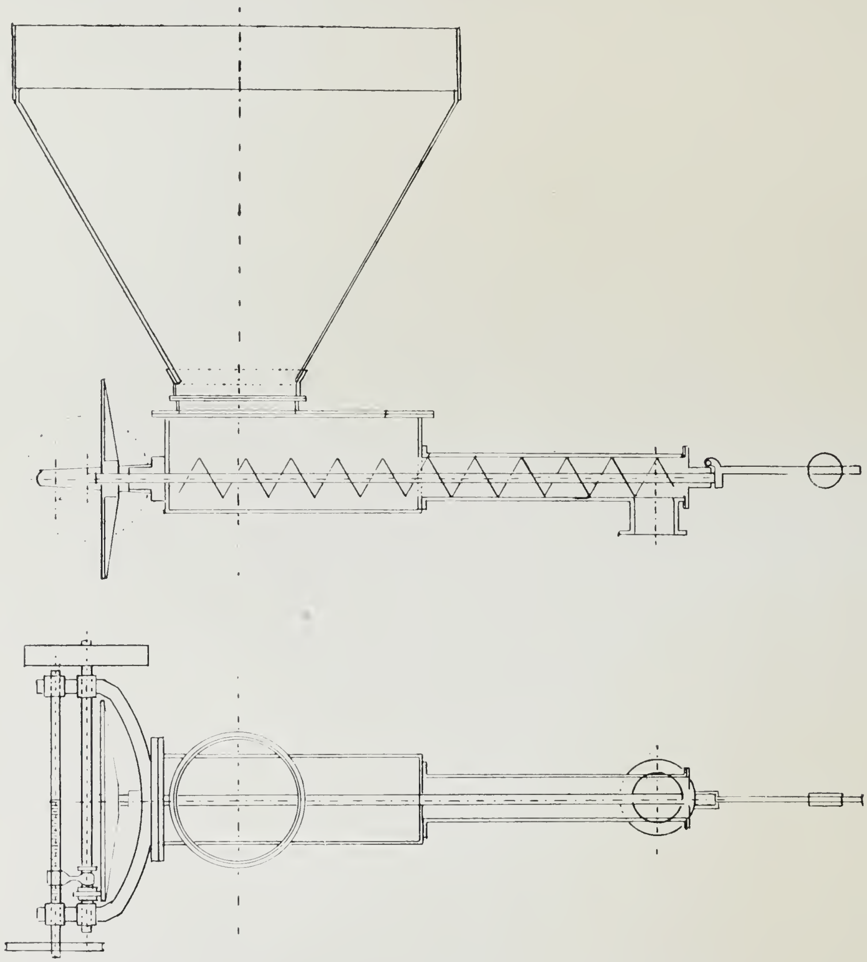

FIG. 132.—Variable Speed Coal-feed Worm (Friction driven).

The use of a double worm for feeding the dust coal and other fine material from the hoppers is to be recommended, as by this means more reliance can be placed upon the regularity of the feed. With this arrangement, a right and a left handed screw is used, the one being driven from the other by means of spur wheels. In certain instances the coal dust descends

directly from the double worm into the pipe, by means of which the hot air passes to the kiln, and together they travel for a distance of often 15 feet. The heated air causes oxidation and decomposition of the coal, and therefore some, though doubtless a small, loss of heat. It may further be a source of danger. The most modern plants have the coal feed so arranged that the coal dust does not come into contact with the hot air until it is just entering the kiln.

This end is obtained by transporting the coal dust from the feed worm by means of a chute to the hot air pipe at a zone near to the kiln hood, as shown in Fig. 134. Another system of conveying the coal from the hopper screws is by means of a blast of cold air from a small fan; it being mixed with the hot air from the clinker coolers just before entering the burning nozzle.

The function of the hot-air fan is sometimes misunderstood. In the

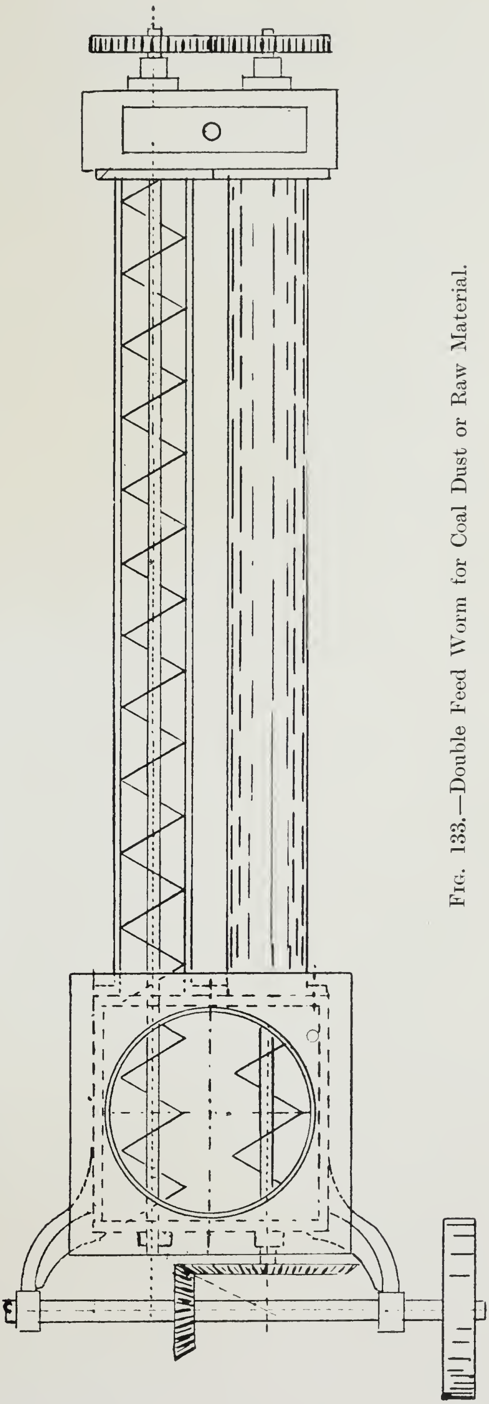

Fig. 133.—Double Feed Worm for Coal Dust or Raw Material.

case of plants employing a fan for drawing the air through the cooler, by speeding up or increasing the size of the fan, only a very slight effect in increasing the draught is obtained. The function of the hot air passed through the nozzle is to disperse the coal dust, and cause its rapid ignition. The main portion of air to complete the combustion is taken in through the cooler, by way of the clinker chute, the rate and quantity of air thus drawn in being governed by the chimney draught. The damper is therefore the means for increasing or decreasing the amount of air taken in. The draught can be conveniently measured by means of a U tube containing lubricating oil, one end of the tube passing through the kiln head and the other being open to the atmosphere.

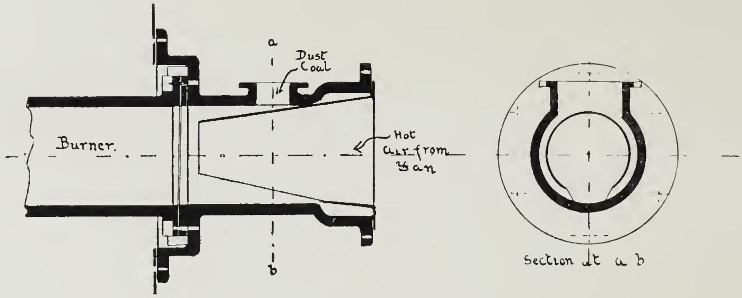

Fig. 134.—Coal Dust Burner Attachment.

When a forced-draught system is employed, the speed of the fan will have some effect upon the draught, if the various joints are sufficiently tight.

In this connection it may be mentioned that the use of the hot-air fan has been entirely dispensed with by Matcham, who employs natural draught to draw the coal dust into the kiln. With this system the coal dust is fed by a worm, the speed of which can be varied, from the coal-dust hopper, and falls into a water-cooled chute, tapering gradually to the point where it enters the kiln. Air is drawn in on all sides of the burner by means of the chimney draught. It is claimed that by this system a more gradual burning effect is obtained, the temperature in the

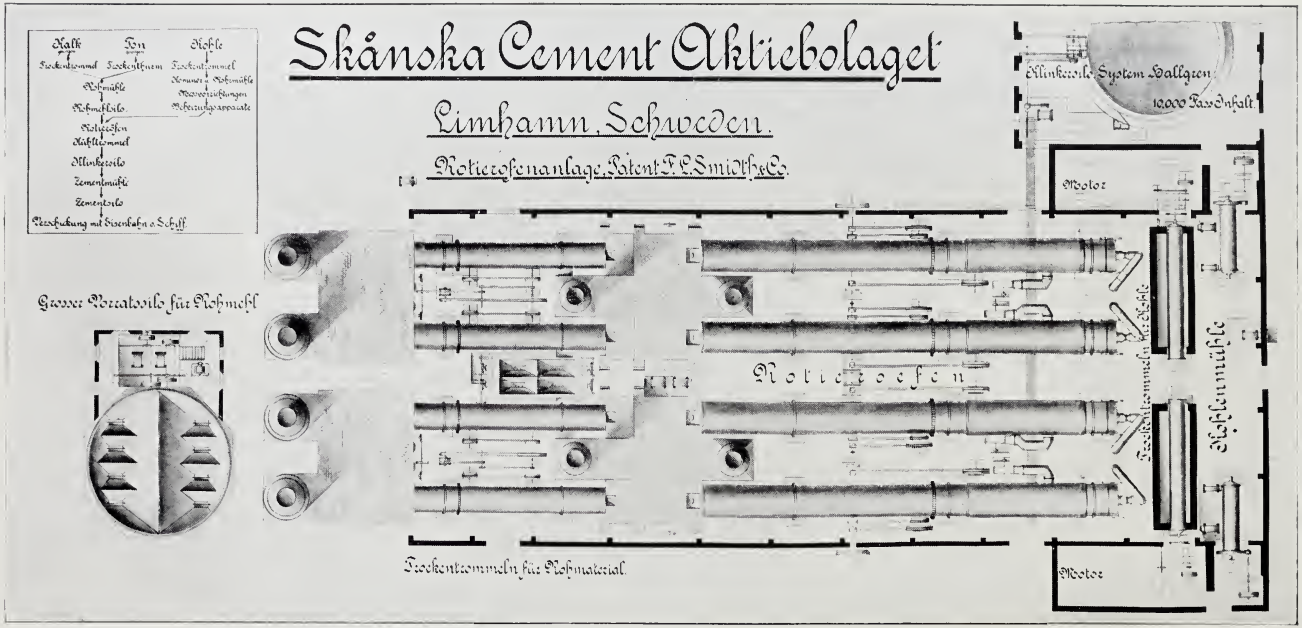

FIG. 135.—PLAN OF KILN PLANT, SHOWING ROTARY KILNS AND DRIERS FOR RAW MATERIALS AND COAL.

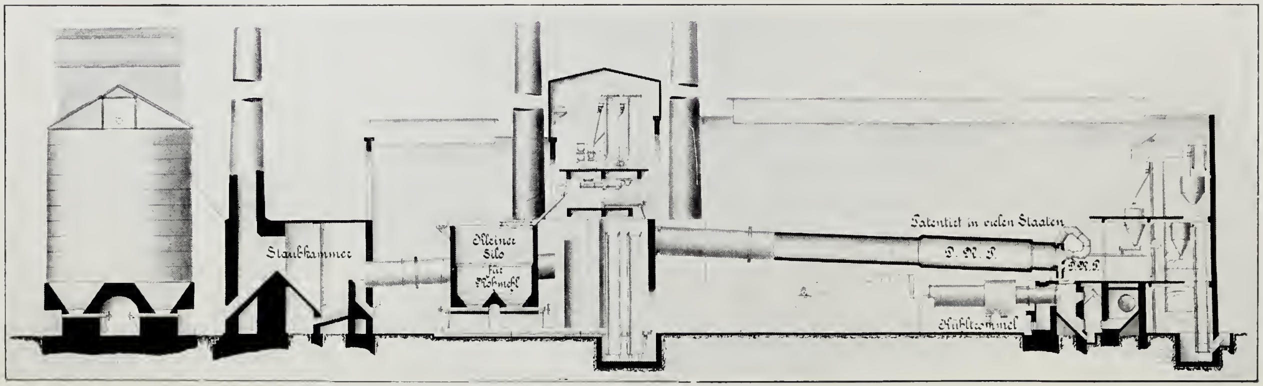

FIG. 136.—SECTION OF ABOVE.

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burning zone being lower and its length greater than with the other systems. A kiln-head provided with this burning arrangement is shown in Fig. 126.

It has already been stated that the kiln gases are frequently employed for drying the raw materials and that the hot air from the coolers is utilised for drying the coal. In this combination the driers and kilns form a closely

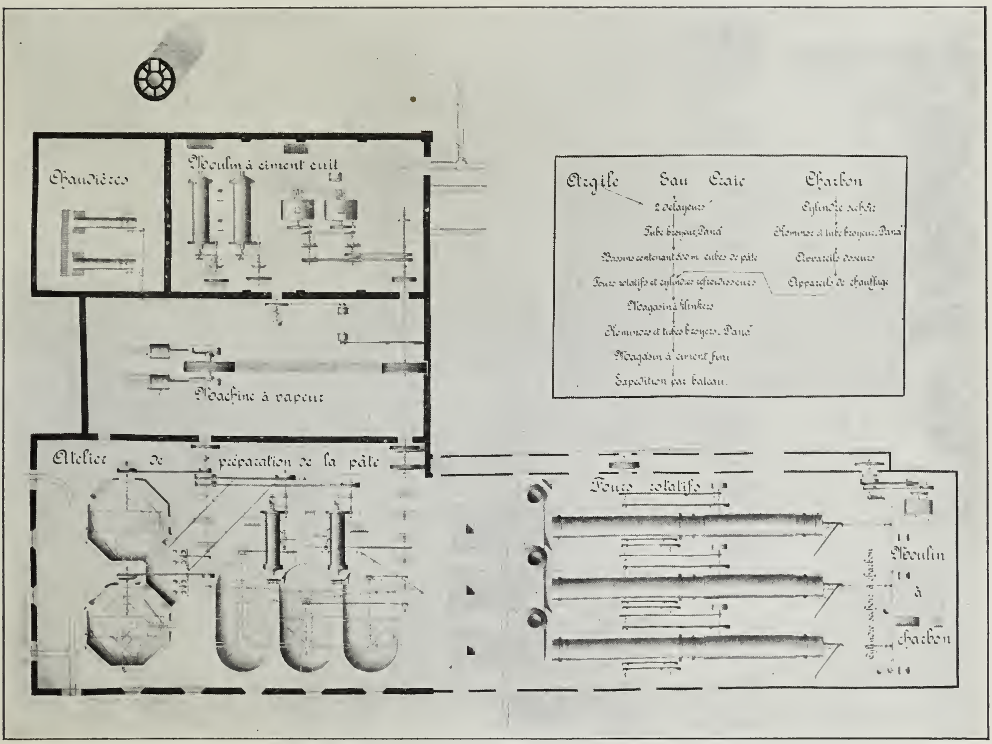


FIG. 137.—Plan of Rotary Kiln Plant Operating on the Wet Process.

connected plant. The arrangement of kiln, cooler, and coal drier is shown in Fig. 119, while the whole lay-out of a kiln plant for the dry process, comprising rotary kilns with enlarged burning zones, forced draught coolers, coal driers heated by hot air, and raw material driers heated by means of flue gases, is shown in plan and sectional elevation in Figs. 135 and 136. In this case it will be seen that each kiln has a separate chimney and that another chimney is provided for

taking up the kiln gases after passing the drier, thus making two chimneys for each kiln. This is, of course, a feature of this individual plant, it being more usual to employ only one chimney in conjunction with suitably arranged flues, for taking the gases direct from the kilns to the open or by way of the driers.

In Fig. 137 a complete cement plant operating on the wet process is shown in plan. From it the general arrangement of wash-mills, mixers, and kilns can be seen.

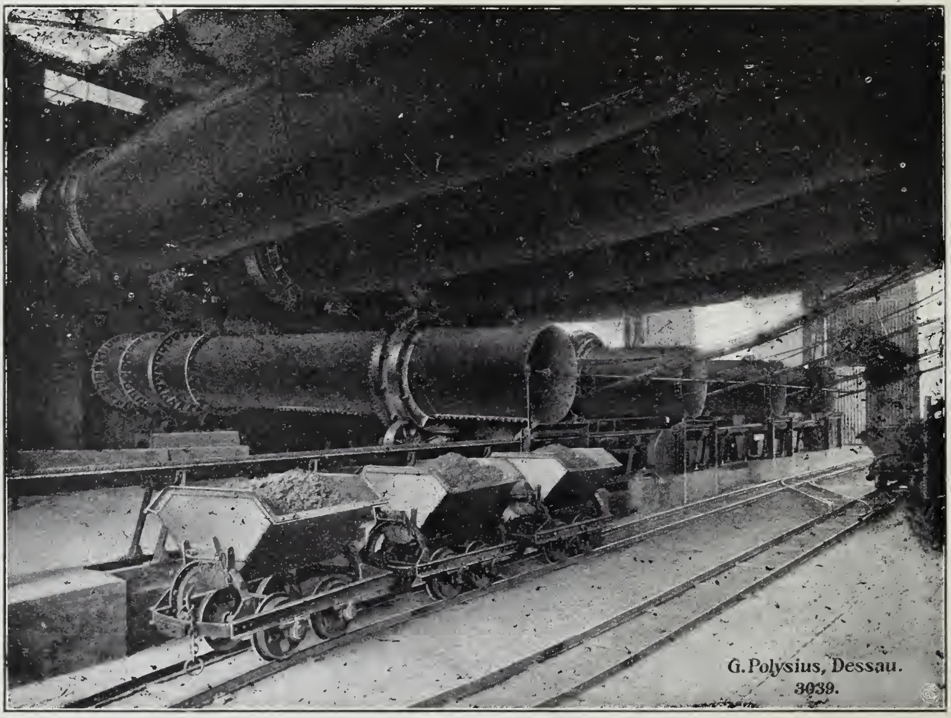


FIG. 138.—Kilns and Coolers at Alsen's Portland Cement Works at Itzehoe.

CHAPTER III

COAL DRYING AND GRINDING

The preparation of the coal for firing the rotary kiln, in the main, follows closely the methods employed for preparing the raw materials by the dry process.

The quality of coal employed is of the bituminous class, its suitability being governed chiefly by the percentage of ash contained in it. Coal containing from 5 to 10 per cent. of ash is to be recommended, although qualities containing up to nearly 20 per cent. are sometimes employed. The influence of a high ash content is shown not by any difficulty in obtaining the required temperature, although naturally a greater percentage of coal has to be employed for burning the clinker, but by the increased tendency to form a clinker ring just beyond the clinker zone. The composition of this formation, and also of the clinker coming from the kiln at the same time as the piece of ring analysed, is given in the following figures:—

	Ring.	Clinker.
Silica	25·73	22·47
Alumina / Ferric oxide	14·02	11·39
Lime	56·52	64·34
Magnesia	2·15	1·04
Sulphuric anhydride	0·32	0·22
Loss	0·16	0·29

The origin of this ring is rendered obvious by the above figures, which, by the way, are selected from a number of results of the same order.

The coal, therefore, must be selected so as to give freedom from this objectionable factor in operation. With raw materials of different composition, the tendency to form a ring varies, so that it will be found that at one works coal containing more ash can be used without disadvantage than

at another. The more silicious raw materials are those which can be burned with a high ashed coal. The composition of the coal ash, doubtless, has some effect in this respect, as also has variations in the percentage of lime in the slurry. These factors, however, have only a microscopic effect in practice, the variation in the percentage of lime which could occur in a well-conducted works or in the composition of the coal ash from any one district would be very small.

The suitability of a coal from the point of view of the amount of bituminous matter contained in it, is determined by a test which is carried out in various ways, leading to the obtaining of different results by different operators with the same coal. If, when the powdered coal is heated in a covered porcelain crucible for twenty minutes over a Bunsen burner, the flame of which is 1 inch from the bottom of the crucible, and afterwards heating the mass in the full flame for five minutes, there is a loss in weight of not less than 25 per cent., the coal may be considered suitable. The above is a rough test which is sufficiently good for the purpose of determining the suitability of a coal for firing a rotary. A better method is to determine the percentage of total carbon, which should equal about 80 per cent., calculated on the basis of dry, ash-free coal.

The percentage of moisture contained in the coal as delivered is a matter of importance, as frequently the drying plant will not deal with coal containing a large percentage of water, and, of course, the water has to be paid for at the price of coal, unless it is collected in transit. The grades of coal usually employed are called "rough small," "slack," "peas," "beans," and "duff." Frequently washed coals are used, and if delivered sufficiently dry they may be quite suitable; "duff," however, is as a rule very wet.

The coal storage should be under cover, and of course should be so arranged that the least possible amount of handling is necessary. The storage must be so dimensioned as to be suitable to the position of the works, large enough to contain, say, 500 to 1,000 tons if the coal is brought by steamers, or smaller if it can be obtained by barge or rail in smaller lots.

From the store the coal is dumped as required into a crusher. For this purpose jaw-crushers are sometimes employed, and occasionally a crusher of the coffee-mill type. The usual means of performing this initial crushing is by means of hedgehog rolls. The grades of coal usually employed in this country, however, may be delivered to the drier direct without crushing.

The coal being sufficiently reduced passes to the drier, which is in the form of a slightly inclined rotating drum, along the interior of which channel irons are riveted and it is set in a brickwork chamber. The drier is heated by a furnace, by the hot air from the coolers, or by a combination of the two. Independently fired coal-driers should be so arranged that the fire does not come into direct contact with the drier drum until sufficiently cooled, to avoid decomposition of the coal, which takes place at a relatively low temperature. A brickwork arch is therefore built over the furnace and carried along a certain distance. A good circulation of the hot gases should be obtained in all cases by arranging suitable baffle walls. A draught of air should pass through the drying drum, and this is advantageously pre-heated; this being carried out preferably by arranging an iron air-duct in the flue beneath the drier, connection between it and the drum being made at the drier hood.

When hot air from the coolers is used it should be made to pass round the drum; the brick chamber in which it is set being formed as a dust chamber with hopper bottom and discharge doors; and then through the drum in the reverse direction to the coal.

With combined furnace and hot-air heated driers the hot air is arranged to pass through the furnace and around the drum.

When starting up a plant in the first instance, or after a stoppage, unless a sufficient stock of dry coal is on hand to start the kiln no hot air from the cooler will be available. It is, therefore, advisable to arrange a furnace to tide over such periods.

The dry coal passes from the drier to a small hopper, and then to the mill. In many plants a ball-mill and tube-mill is

employed for preparing the coal, which in the most modern practice is ground to leave a residue of about 15 per cent. on the 180-mesh sieve. The effect of finer grinding is to shorten the flame, resulting in a higher temperature at the burning zone, and therefore increased economy in fuel, as in the upper portion of the kiln a relatively low temperature is required for driving off the carbon dioxide. With very coarse coal, 35 per cent. on 180, the temperature in the kiln is very low for the first 20 feet. In some cases a sieveless ball-mill or short tube is used in conjunction with an air-separator. Messrs Krupp supply a mill called the double grit-mill, which consists of a pair of tube-mills loaded with steel balls. The two tubes are arranged one above the other. The coal is fed in pieces up to the size of a nut into the upper tube through which it passes, and by means of a chute and feeder to the lower tube. The Compound mill may also be employed for coal grinding, as indeed may any of the other mills mentioned in the earlier portion of the book.

The Williams mill and the Jeffrey swing hammer pulveriser are frequently employed in America for grinding the coal to grit fineness, the finishing being carried out by a tube-mill or air separator.

Centrifugal ball-mills, pendulum-mills, and the mills of the Kent type are all used for coal grinding, the former without any finishing machine, and the latter in combination with the tube-mill or air separator. Crushing rolls with rifled shells may be used for the preliminary treatment of coal to be afterwards ground in mills of the above type, the wear and tear on them being reduced by this means.

From the mill the coal dust is conveyed to hoppers arranged above the kiln platform, the capacity of these being great enough to hold from 4 to 6 tons of coal dust. The advantage of having a stock of fine coal ready for delivery to the kiln is obvious.

Several disastrous fires and explosions have occurred at cement works owing to the accidental ignition of the coal dust. The majority of these have arisen through the carelessness or ignorance of the workmen. The coal mill should be well ventilated, and any accumulation of dust prevented.

No naked lights should be permitted near a coal mill, and, of course, no smoking should be allowed. Incandescent electric lamps should be provided with air-tight cases. No riveting or other operations requiring heat should be carried out in the vicinity.

Coal dust and the dry unground coal have occasionally become ignited: one possible and avoidable cause of this is overheating of the coal in the drier. There are, however, occasions when the origin of such a fire is obscure: the prevention of any currents of air passing through the dry coal will tend to eliminate such a possibility.

BOOK IV

THE TREATMENT OF THE CLINKER AND THE FINISHED CEMENT

CHAPTER I

STORING AND GRINDING

The clinker coming from the coolers may pass directly to the mills, or it may pass to some form of store, depending upon whether it is desired to grind the fresh clinker, or to grind only stored stuff. Storing for a period, preparatory to grinding, has the advantage that the water, sprinkled on to the clinker for regulating the setting time, gradually combines chemically with the constituents of the sintered product and is consequently not driven off in the grinding process to such a degree. The evolution of steam in the mills is a cause of some considerable inconvenience, leading as it does to the choking of sieves and screens, thus reducing the output of the mill. It is stated that clinker which has been stored for about a month is more easily ground. While this is true as regards some clinker, in many cases little or no softening results from such storage. The duration of this period of storage is from a fortnight to six weeks, and a statement has recently been published to the effect that after such treatment the clinker will fall to a coarse meal mixed with lumps. Such a change does not always take place with rotary clinker even after a year's storage. The degree of burning has some effect in this connection, but of much greater effect is the composition of the clinker. The more aluminous clinkers seem to fall more readily than those which are higher in silica, while the presence of relatively coarse silicious matter,

although fine enough to pass the 180 mesh sieve, in the raw materials seems to have some influence in the same direction. Low limed clinkers invariably fall, often to such an extent that 95 per cent. will pass the 120 mesh sieve, a fact that is well demonstrated by a piece of clinker ring.

There are, however, factors necessarily connected with the practice of grinding stored clinker which are inimical to cheap production. For example, the clinker has to be handled twice, and further, expense is involved in the construction of suitable storage accommodation.

The point at which the storage of clinker presents an actual gain can only be determined by experiments on the manufacturing scale which will indicate the actual increase in hourly output. This figure having been obtained it should be a matter of no great difficulty to calculate the exact position in the two cases, and to estimate the amount of money that might be profitably employed in putting in a large clinker store and mechanical handling appliances. The point at which there is neither profit nor loss is shown when—

$$\frac{T_2\left(L + \frac{IS}{100T_T}\right) + P + W}{T_2} = \frac{P + W}{T_1}$$

where T_1, T_2, and T_T are respectively the output when grinding fresh clinker, stored clinker, and total output per annum; L is increase in labour, power, and repairs involved in storage system; S, cost of store and plant; I, interest and depreciation on same; P is the cost of power; and W the cost of wages per running hour of the mill.

The above refers only to the provision of a store for the purpose of softening the clinker by "atmospheric action," as it may be called.

It may be advisable to provide a clinker store for a variety of other reasons. For example, it is advisable to have a reserve of clinker upon which to draw at periods of abnormal demand or interruption of the working of the kilns. Again it may be that where there is a long and severe winter, when very little cement would be used, by storing the clinker during this period a kiln plant of reduced size could be

installed; although it is more general to store the finished cement, keeping the mill running full time during this period instead of part time as the other system would necessitate. In most cases the cement mill is run from five and a half to six days out of the seven, and storage accommodation is therefore provided to take the kiln output during the stoppage.

The cheapest form of clinker store from the point of view of construction is a concrete floor with such retaining walls as may be necessary and without any form of covering. Such a system, however, has the disadvantage that, in a season of long rains, the clinker becomes thoroughly soaked with water and it becomes quite impossible to prepare a cement from it having a reasonable setting time. In certain works the clinker from the coolers falls into skips which, when filled, are run out and tipped into the boot of an elevator, or on to the floor of the clinker yard. After the desired period of storage the clinker is shovelled into skips and run to the mill. The cost of such treatment may be as much as sixpence per ton, while if the clinker was taken by mechanical means to the mills from the coolers, the cost would not equal one penny. The use of a shaking or a band conveyor, and an elevator provided with a distributing chute, will of course dispense with one portion of the handling, and the clinker will be delivered on the floor of the yard at the lowest possible cost, but with a flat floor men must be employed for digging the clinker and feeding it into the return conveyor, unless a movable scraper conveyor is employed for conveying the clinker to a fixed shaking or belt conveyor arranged beneath the floor of the clinker store as shown in Fig. 139.

The construction of a hopper-bottomed storage silo necessitates a considerable initial outlay, but when installed, such a system has the advantage that the labour costs are reduced to a minimum in consequence of the ease with which it lends itself to mechanical devices for handling the clinker. In cases where it is decided to have a flat floor upon which to store the clinker, a tunnel should be arranged beneath the floor in which an oscillating conveyor can be operated. This conveyor is provided with openings at intervals by

means of which the clinker, fed on to it by the conveyor running below the discharge ends of the coolers, may be

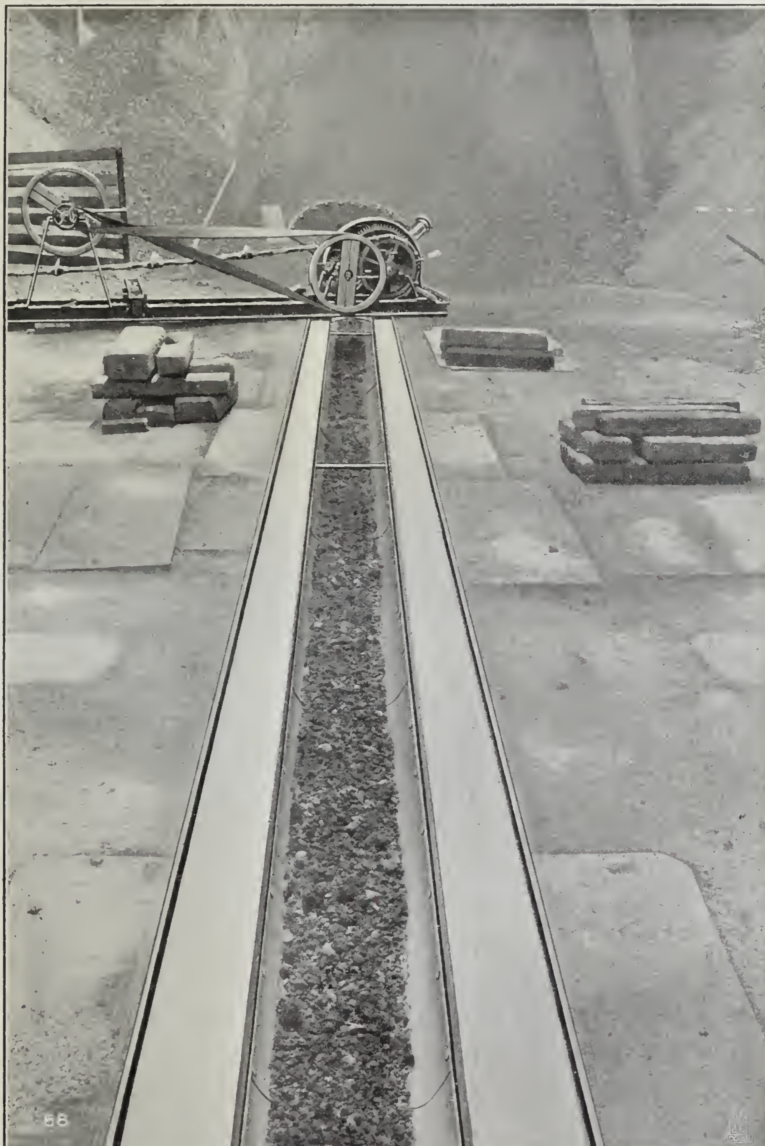


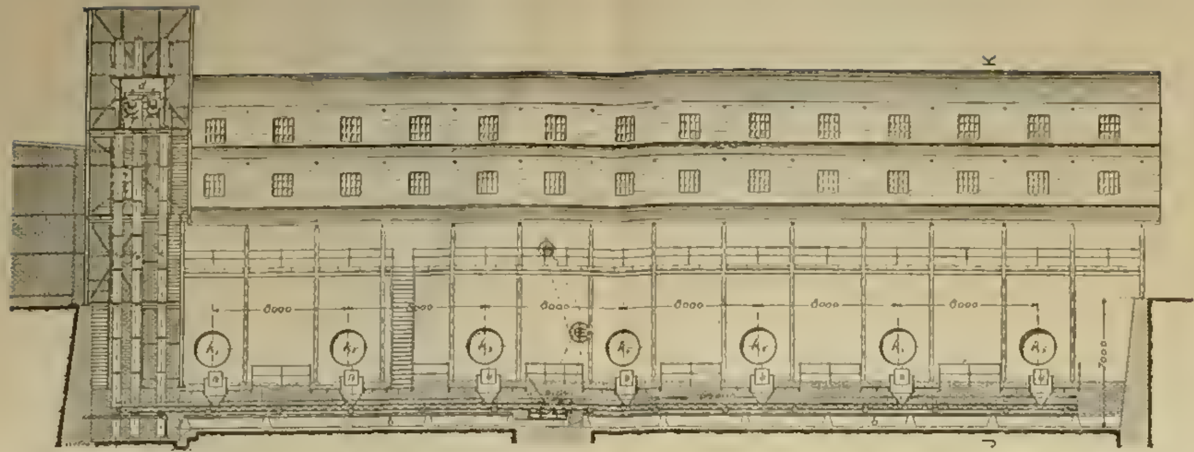
Fig. 139.—Clinker Store with Movable Scraper Conveyor feeding on to Shaking Conveyor.

dropped at will into the boots of elevators arranged below them. These elevators are provided with distributing chutes

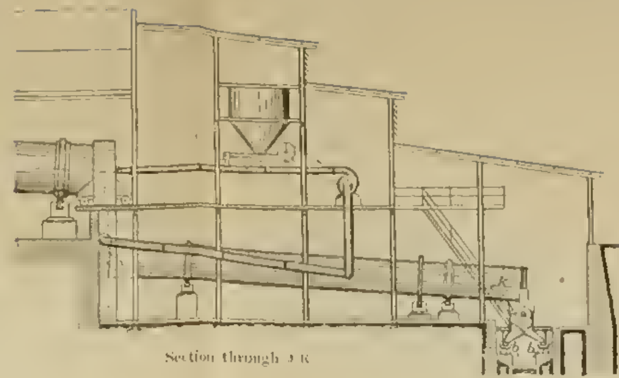
and by means of them the clinker is spread over the floor. At the end of the conveyor an elevator is provided for taking the clinker to the feed hoppers in the mill, either direct from the kilns or from the store, by means of openings in the floor, the same conveyor being used for both purposes. Another system for storing clinker, or coal for that matter, is between embankments of earth or similar material faced with concrete. The slope of these embankments should be steep to obtain a satisfactory automatic discharge: an angle of about 30 deg. to the horizon is suitable for this purpose. In a tunnel below the channel formed between these embankments a conveyor is placed; the clinker being loaded on to it by means of chutes provided with suitable gates. An arrangement of this type is fully illustrated in Fig. 140. Large hoppers are frequently employed for storing clinker; they may be constructed in brickwork or reinforced concrete and need no special description. A form of silo for storing clinker and other materials presenting some novel features consists of a plain cylindrical chamber, the bottom of which is so shaped that it forms a number of hopper-shaped discharges. An illustration of a silo of this type is given in Fig. 135, from which it will be seen that the bottom is in the form of the frustum of a cone, and inside it is divided into two sections by means of a wedge-shaped partition from which a number of smaller partitions at right angles extend to the side walls. Steel is occasionally employed for the construction of clinker hoppers of large dimensions, but this material is chiefly used for the smaller hoppers to contain only from 10 to 20 tons.

The grinding of the clinker is performed by means of various machines and many different combinations. The individual mills have been described at some length in the section dealing with dry grinding machinery. It remains, however, to give a general review of the process.

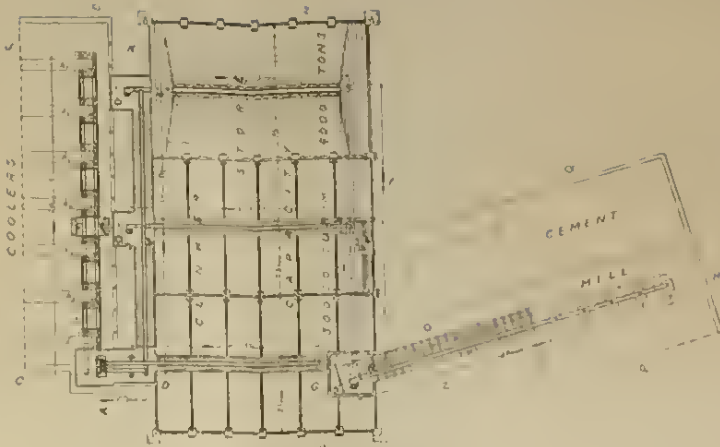
The clinker as it comes from the kilns is rarely ground without an addition of some material to regulate the setting time. More especially is this the case with rotary kiln clinker which, as it comes from the coolers, cannot be turned into a marketable product by merely reducing it to powder.



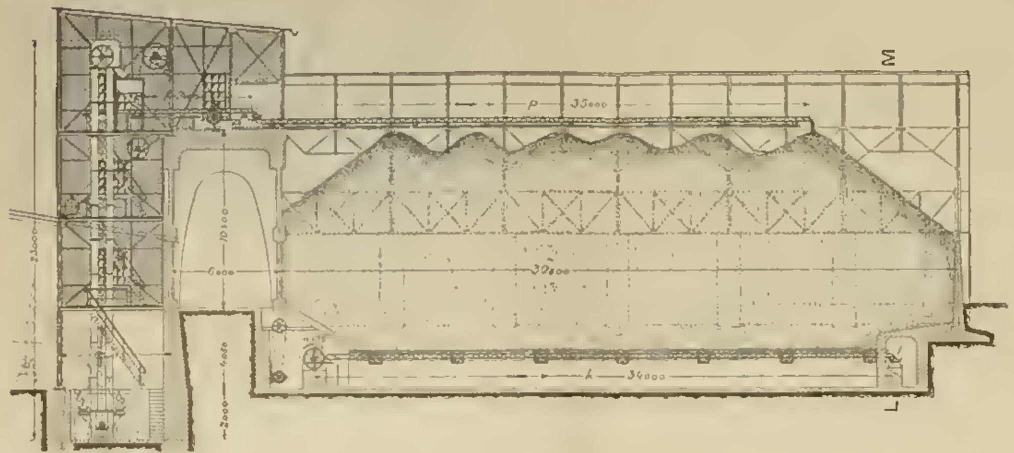
Section through A-B.



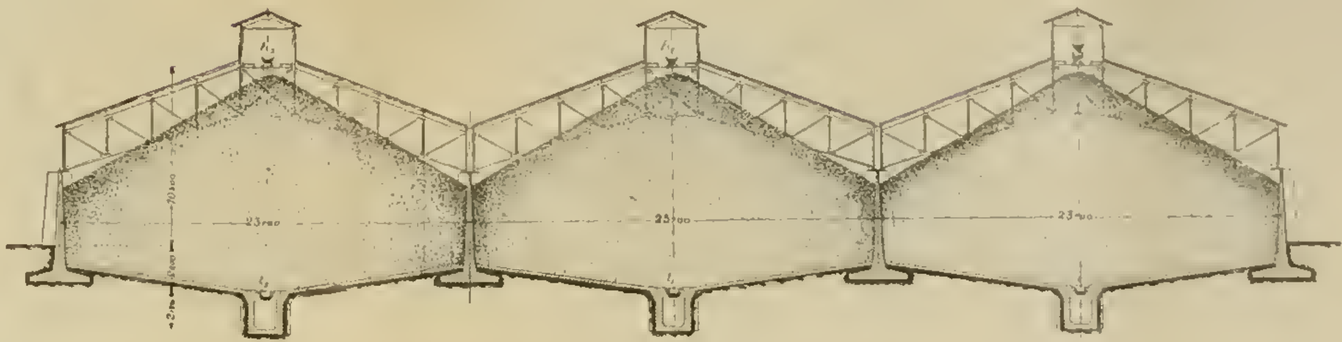
Section through J-K.



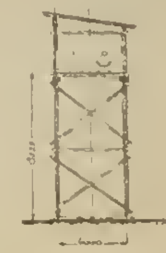
Plan. (Scale 1 in 1,000.)



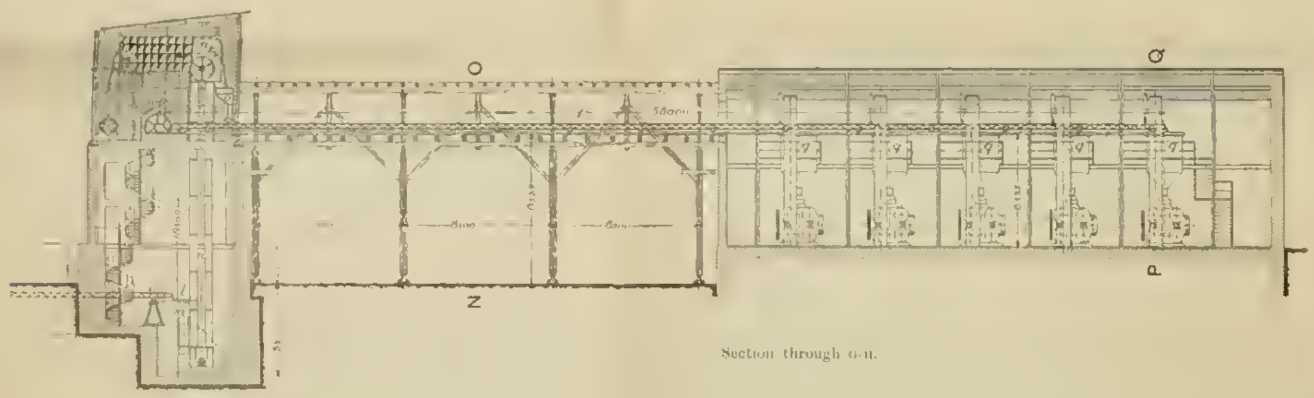
Section through C-D to E-F.



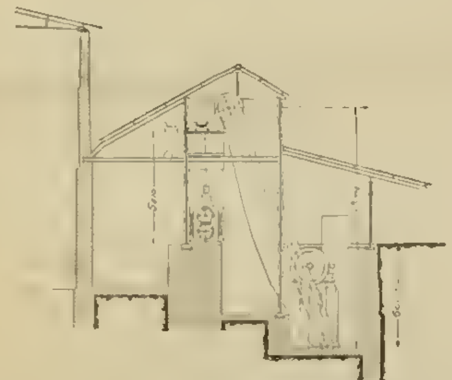
Section through L-M.



Section through N-O.



Section through G-H.



Section through P-Q.

A COMPLETE CLINKER HANDLING AND STORAGE PLANT.

Conveying capacity, 50 tons per hour.
Storage capacity, 4,000 tons clinker.
MARCUS CONVEYORS throughout.

Scale, 3 in 1,000. Plan Scale, 1 in 1,000.

FIG. 140.

[To face page 234.

The fact is that the rotary kiln clinker when ground to powder sets instantaneously, and some means has to be adopted for overcoming this inconvenient property. In the early days of the rotary kiln in this country, the amount of advice which could be had relative to the regulation of the setting time was very great and its value the reverse. For example, it was stated that to obtain a suitably slow setting cement, the clinker must be high in lime, but now, every one with the least experience in the manufacture of cement knows that high liming is without effect, at least unless a cement with a higher expansion as shown by the Le Chatelier than 50 mm. is produced. Few experimenters care to go beyond this point, and there is therefore a paucity of information with regard to the behaviour of cements which are even more worthless. The fact is, that between a cement with 62 and another with 66 per cent. of lime, there is no difference with regard to set unless some addition is made. It has also been stated that by burning the cement in an oxidising atmosphere a slower setting product is obtained. If this means anything it means that an excess of oxygen should be present in the gases coming from the end of the kiln: in which case, as a result of repeated tests, the writer has no hesitation in characterising this theory as fallacious.

Actually, the setting time of rotary kiln cement can be regulated with no great difficulty, and for this purpose hydration and the addition of calcium sulphate are the means most usually adopted. The amount of water and of gypsum which has to be added varies slightly with the cements produced from different raw materials, and is largely dependent upon whether pure rotary clinker or a mixture of rotary and shaft kiln clinker is ground. Some means for the addition of water and of gypsum, therefore, should form an integral part of the cement mill. The watering of the clinker as it comes from the kilns by means of a perforated pipe provided with a valve and connected to the water supply is often the only provision that is made for such hydration, and in many instances this is sufficient. The hardness of the clinker, and the time that elapses between the addition and the grinding, largely condition the amount of water which it is possible to add without

detrimentally affecting the output of the mill. As a general rule, the percentage of water which can be introduced in the cement without causing such inconvenience, the freshly wetted clinker passing direct to the mill, is less than 2 per cent. Storing of the clinker will enable a larger percentage of water to be absorbed, and less will be given off as steam in the mills, but this method of watering is not always convenient, and some means is of necessity adopted for introducing the water either during the grinding process or subsequently. A number of firms employ a system of hydration by means of steam injected at the feed end of the tube-mill. In such cases the feed worm of the tube-mill is mounted on a hollow shaft through which the steam is blown. The use of low-pressure steam has been found in the author's experience to be more effective than high-pressure or superheated steam. The explanation of this seems to be that a low-pressure steam contains more water, volume for volume, than does high-pressure saturated or superheated steam. Furthermore, saturated steam will deposit water more rapidly than will superheated steam, and that for obvious reasons. The velocity at which the steam is ejected from a nozzle of given area is also less the lower the pressure, and, therefore, the tendency for it to be blown through the mill is less. The effect of temperature on the absorption of water by cement has been studied by Montmartini, and he finds that at a temperature of from 70 to 75 deg. Cent. air saturated with water but free from CO_2 does not hydrate but actually causes the expulsion of any water contained in the cement. It is, therefore, to be concluded that the hydration should be carried out at as low a temperature as possible.

The devices for hydration in the tube-mill need no special description, as they may be of the simplest type. In certain instances hydration of the cement is performed in the conveyor leading to the storage bins. In this case, care should be taken to, as far as possible, prevent drops of water formed by condensation falling into the meal, and as an additional safeguard a grid may be provided for the separation of such lumps as may be produced.

Calcium sulphate is added in the form of crude, roughly ground gypsum or as plaster. Most usually it is employed in the form of the coarsely ground mineral, as little difference between the action of the two forms is observed in practice; and naturally the mineral is cheaper than the burnt product. In many works a measured volume of gypsum is added to a measured volume of clinker, the percentage of gypsum added being regulated by using boxes of different sizes, and so proportioned as to contain a quantity equal to $\frac{1}{2}$, 1, $1\frac{1}{2}$, and so forth per cent. of the weight of clinker contained in each barrow or skip delivered to the mill hopper. In the majority of works, however, the gypsum is now added by an automatic feeder, which can be regulated so as to deliver varying percentages. The position of this feeder depends largely upon the type of grinding plant in use, but it should always be so arranged as to add the gypsum before the grinding operation is completed. A hopper, provided at the bottom with a worm rotatable at different speeds, can be used for this purpose, or a table feed such as that manufactured by Smidth, or a plunger as manufactured by Polysius can be used if suitably dimensioned. A simple form of oscillating feed may be employed. With this device, the quantity of material delivered per unit of time is varied by altering the size of the opening, and a scale may thus be made indicating the percentage which is being added. All the forms of gypsum feeds described add a certain proportion of material per given interval of time, and the regularity of the quantity added to the cement depends upon the uniformity of the output of the mill. In the ordinary way this is sufficiently good, as the irregularities in this respect which occasionally occur are either momentary or of gradual development, and are, therefore, either negligible or are discovered in the ordinary routine of testing without any harmful effect on the quality of the cement.

The actual reduction of the clinker to a meal-like product is in certain cases performed in one operation, a crusher being employed to break up any large pieces, reducing all the clinker to material of the size of a hazel nut. Comparatively few machines are capable of performing the reduction

in one stage without some accessory plant, but the various types of pendulum mill and the centrifugal ball-mill can be successfully employed for this purpose. The one stage reduction system is, however, falling into disuse, for it has been found that with mills of the type mentioned above, better results are obtainable when the clinker is fed to them in the form of a coarse grit. The use of a mill in conjunction with a separator of either the sieve or pneumatic type is not uncommon practice, the Kent mill and the sieveless ball-mill being employed in several works in conjunction with air separators, as also is the short tube-mill.

The greatest proportion of the Portland cements manufactured at the present day are finished by means of tube-mills, and the mill most used for granulating or preparing the material for treatment in these machines is the ball-mill in one or other of its various forms, but in certain cases other types of coarse grinder are employed. The wear and tear in grinding rotary kiln clinker is considerable, and it is found generally that the cost of upkeep with certain types of mill exceed the amount saved by their somewhat smaller consumption of power, and their lower initial cost. It must be added, however, that the ball-mill is not altogether an ideal machine for reducing rotary clinker to grit.

With regard to the employment of separators in the manufacture of cement a great deal has already been written. At one time the only practical means of economically separating a product of the fineness of cement was the air separator, and it was said of this machine that it destroyed the uniformity of the product. A few years ago this opinion was held generally, but nevertheless a number of firms installed sieveless ball-mills in conjunction with air separators in the raw-mill, the coal-mill, and in the cement-mill. These plants have been in operation continuously since then without any such difficulty being experienced in practice. The sorting out of the particles of different specific gravity which some people expected has not resulted in actual operation, and this for an obvious reason. If two materials of different specific gravity, A and B, are ground in a ball-mill and passed through a separator, and in the first passage

A the lighter or more easily ground was separated to a certain extent, a greater proportion of B would be returned to the mill, which would then contain a larger proportion of B than of A, and upon this passing through the separator an increased quantity of B would be discharged into the fine meal. Many results proving that this works out in practice have been published. Among the latest figures is a case given in an issue of the *Tonindustrie Zeitung* of the current year. In this case the materials were a practically pure limestone and a clay containing 10 per cent. or thereabouts of calcium carbonate. As a result of extensive trials it was found that the variation in percentage of calcium carbonate in the finished product varied to the extent of 1 per cent. above or below the mean, while the percentage in the clay varied nearly 2 per cent. above or below the mean. The proportion of calcium carbonate to argillaceous matter was roughly 3 : 1.

It may be definitely stated that the use of air separators is now rapidly increasing in all branches of dry grinding. Inclined vibrating wire sieves are also being adopted, and probably at a relatively more rapid rate, illustrating that another objection to sieves in general is also dying out. This objection is raised on the ground that by their employment there is a tendency to produce what might be described as a very fine grit of uniform grade without any great proportion of the finest flour. It would be quite possible to carry the application of sieves to such a degree that this would be true. It is also quite possible to waste power by grinding a mixture of coarse particles mixed with a large proportion of fine stuff. This is well illustrated in the case of a ball and tube mill plant. Feed the tube with a grit leaving 10 per cent. on the 20-mesh sieve, and feed it with a grit similarly graded, but leaving nothing on the 20-mesh sieve, noting the difference in the output having the same fineness, and the truth will be demonstrated.

It is impossible to state in a few words the exact requirements with regard to the degree of separation that can be carried out without interfering with the other qualities of the

cement, as it will vary with different grinding plants and with the grades of product fed to the mills.

Schemes illustrating the most usual arrangement of Clinker Grinding Plant.

Note.—With rotary clinker the crusher and sorting grate can be omitted, as only in exceptional instances is any quantity of material larger than a hazel nut produced by this form of kiln.

I.

Kiln and or Yard

Sorting Grate.

(Smalls.) (Lumps.)

Crusher, Gyratory or Reciprocating.

Ball-Mill or Pregrit-Mill.

Tube-Mill or Separator.

Silo.

II.

Kiln and or Yard.

Sorting Grate.

(Smalls.) (Lumps.)

Crusher.

Pendulum or Centrifugal Ball-Mill.

Silo.

III.

Kiln and or Yard.

Sorting Grate.

(Smalls.) (Lumps.)

Crusher.

Kent, Ring Roll-Mill.

Separator (Coarse Screen).

Fines. Residue.

Tube-Mill.

Silo.

CHAPTER II

WAREHOUSING AND PACKING

Although cement can be made by the means available at the present day so as to be quite suitable for use immediately it comes from the mill, a number of users have a strong objection to accepting deliveries of cement which is many degrees above the temperature of the air. Their objections are based on fallacious views of the cause of the difference in temperature, which is the result of the mechanical work performed on the cement while in the mill, and not the hydration of the "free lime" in the clinker. Partly on account of the tenacity with which such opinions are held, but principally on account of convenience, the cement is delivered into warehouses or bins from which it is loaded after a period of storage. The convenience arises from the fact that it is possible to hold a stock of several qualities of cement, each being suited to a particular class of order.

The suitability of the cement to different classes of work is largely conditioned by its setting time, and it is possible to divide the orders into three classes: those which are for slow, for medium, and for quick cement. In different districts the demand for cements having the various setting times varies, and it is also largely influenced by the season. It may be taken as a general rule that two cements, slow and medium, will be required continuously; and therefore two bins will have to be ready for discharging at any time. For the reason that a run of slow or quick cement from the mills is sometimes obtained, it is necessary that at least two more bins should be available for filling, while others should contain cement which is cooling and which will be sent out as soon as the bins which are being emptied are exhausted. It has been said that the cement can be sent out as it comes from the mill, but it leads to confidence, both among customers

and the manufacturer's staff, if it is possible, and it is made a practice, to get out tests of the average of the cement filled into the bins with mechanical tests over a twenty-eight day period. It is quite possible to predict with great accuracy the character of the cement as soon as the soundness tests are known, or even as a general rule from partial analysis of the sample only, if the various manufacturing processes are carried out with uniformity. Nevertheless, it will be found convenient to have storage capacity for a minimum of a month's output both for the reasons given above and to tide over periods of temporary slackness or abnormal demands. In countries where lengthened periods of frost are experienced, the storage capacity must be greater, so as to prevent the shutting down of the works for a lengthened period: it being obviously more profitable to run a plant for the whole year and to stock cement for six months of that period than to have a plant of double the size shut down for a like period and only giving the same effective output. In America the storage capacity of the warehouses may be equal to holding a six months' output, and it is uncommon for a plant to have a smaller storage capacity than will contain the output of three months' working.

The construction of the warehouses employed in different works differ both in the material in which they are constructed, and also fundamentally in design. The bins may be constructed so as to be suited for loading by manual labour or they may be constructed so as to be suited to the employment of automatic sacking or barrelling machines.

In England the majority of works have flat-bottomed bins from which the cement is dug and loaded by hand, the use of the Simon's sack filler being often dispensed with. This form of bag holder consists of a tripod supporting a cast-iron cylindrical funnel which fits the mouth of the bag. In use a bag is opened out and its neck placed round this collar, a leather strap encircles the mouth of the bag and is fastened by means of a simple clip. The cement is shovelled into the mouth, and when full the bag is dropped on to a trolley run up by a lad to receive it. The weight is adjusted by running

the bag and trolley to a weighing machine after which it is run into a truck.

The design of a typical warehouse of this type is given in Fig. 141. The use of two ramps for loading permits of a cart road being provided on one side, with rails on the other; or if the works are on a canal or river, the warehouse may be so arranged that the cement can be loaded direct on to the wharf on one side and on to rails on the other. In the design

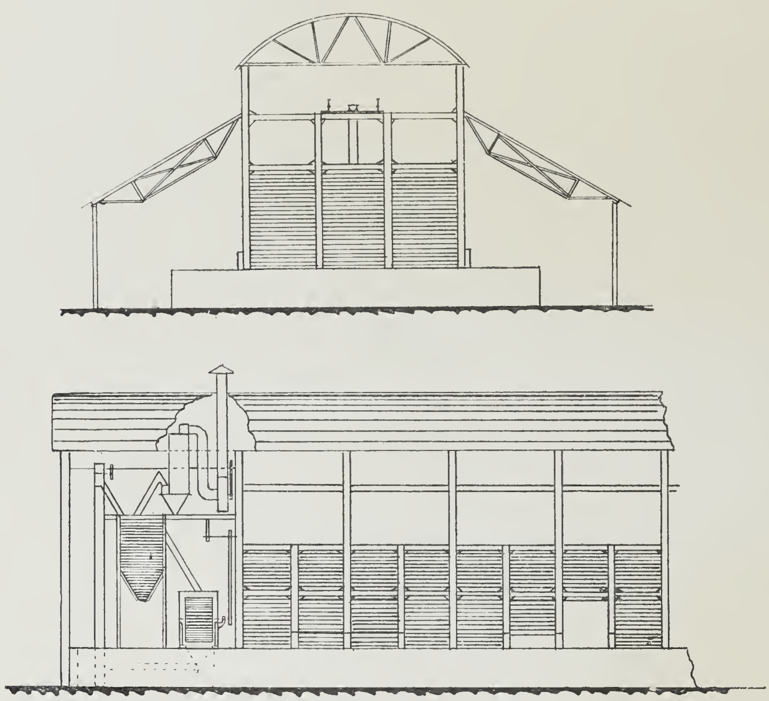


Fig. 141.—Warehouse with Flat-bottomed Bins (showing one bin partly opened).

shown, the loading platforms and storage floor are formed of mass concrete upon such foundations as may be required. The roof and walls may be of corrugated iron, reinforced concrete, or brickwork either plain or reinforced. The partitions between the bins may be of timber or reinforced concrete in 10-foot panels supported by columns in reinforced concrete or rolled steel, and the fronts of the bins may be similarly constructed except for the gates which should be of timber 3 inches by 9 inches by 8 feet. These gates should be of

ample width to allow a gang of, say, ten men to work with ease, and 16 feet will be found to accommodate this number. The arrangement of the boards shown in the figure will be found to be most convenient, as the removal of the two bottom boards can be effected without disturbing the others. The cement will pour out from the opening thus made for some time, and the remainder will be left in a heap sloping away from the opening; the remaining boards may then be successively removed.

The use of bins with slightly sloping floors is very common in America and on the Continent. In such cases a tunnel is constructed at the lowest position, and with doors opening into the bin. Screw conveyors are placed on either side of this channel, and the cement falling into them is

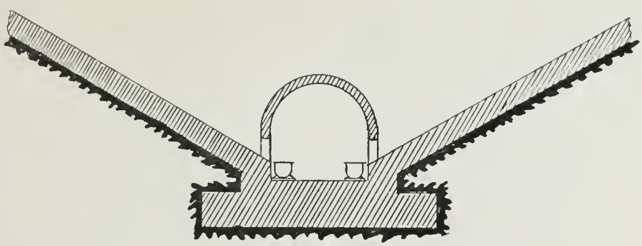


FIG. 142.—Section through Floor of Bin, with Sloping Bottom.

transported to another conveyor at right angles to them. By means of this conveyor and elevator the cement is carried to a distributing hopper, beneath which automatic sack and barrel filling machines are arranged. Scraper conveyors are sometimes used for unloading such bins, in which case a shield protecting the chain from the direct pressure of the cement is provided.

The floors of the bins just described are inclined at an angle of 30 deg. to the horizon; with the narrower hoppers, such as those usually employed on the Continent, the slope is much greater, the inclination being 60 deg. In Fig. 143 the cement silo at a works in Silesia is illustrated, the total capacity of which is about 2,500 tons. This silo is constructed entirely in reinforced concrete and is divided into twelve cells, each 4 metres square in horizontal section. At

the end of the building there is a staircase, and the elevators for the cement are also located in this section. Worm conveyors distribute the cement into the cells, and sack-filling and weighing machines are provided below ten of them, while

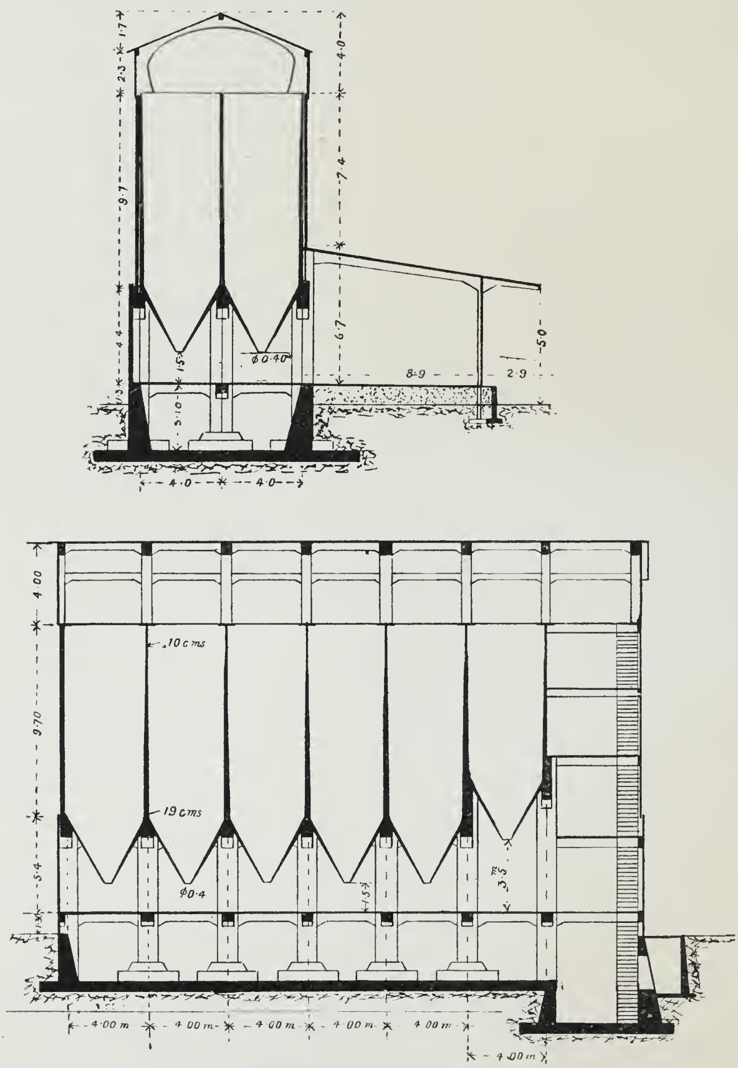


Fig. 143.—Section of Hopper Silo at a Cement Works in Silesia.

cask-filling and packing machines are arranged beneath the other two. The bags or casks are taken on trolleys and run into the wagons alongside the ramp. To protect the cement contained in the cells from damp a ferro-concrete wall 7 cm.

thick surrounds the cells, leaving an 8 cm. wide air space between. The satisfactory emptying of these cells depends

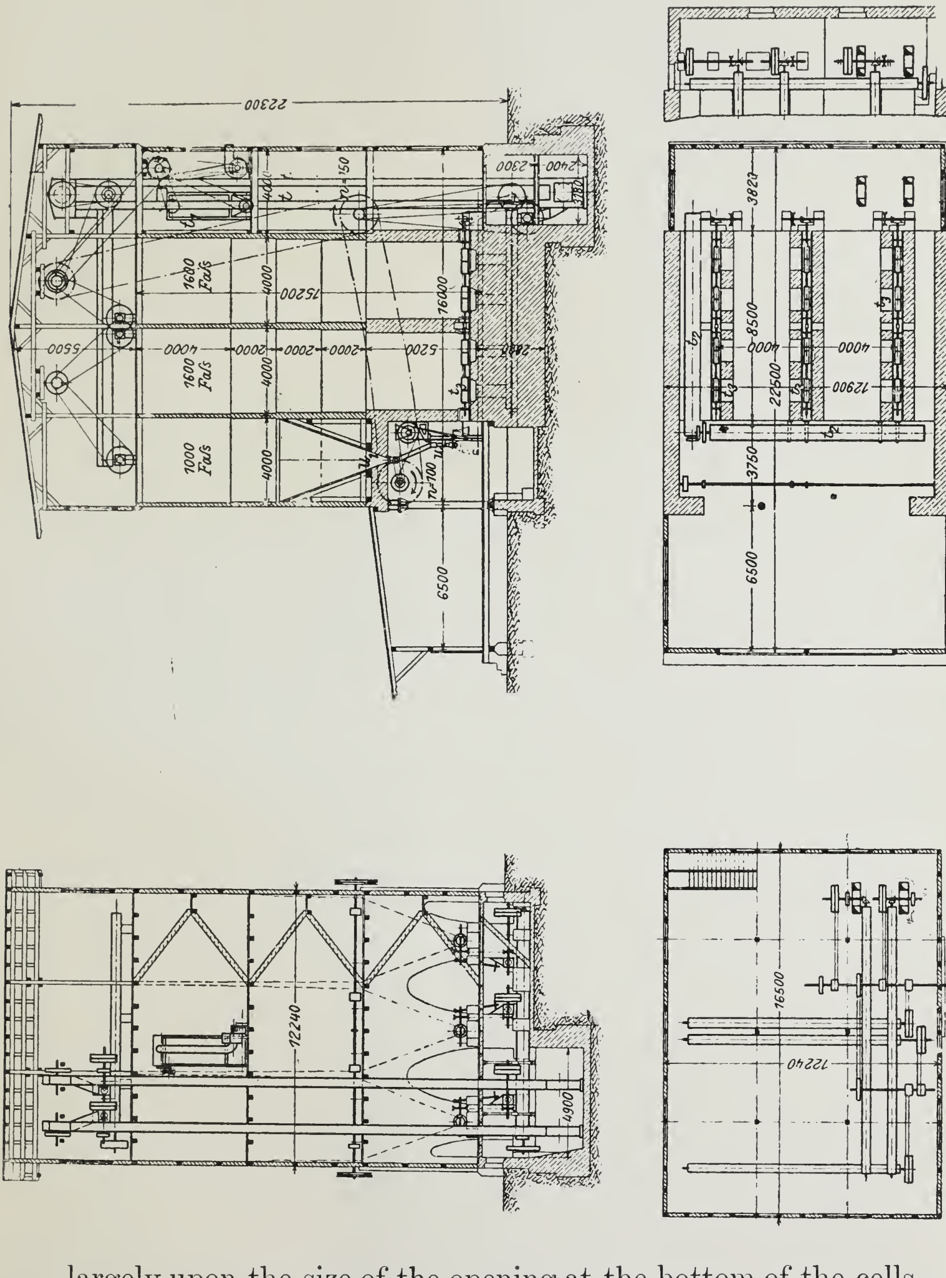


Fig. 144.—Cement Silo at Rudelsburg.

largely upon the size of the opening at the bottom of the cells, which in those described measures 15 inches by 15 inches.

The cost of erection of silos of the foregoing type is given as £4,000 for a warehouse to contain 4,000 tons of cement: the cost per ton decreasing as the capacity increases.

The silo erected by Messrs Amme Giesecke and Konegen at the Portland-cement-fabrik Rudelsburg is illustrated in Fig. 144.

It has a capacity of 2,100 tons, and consists of two rows of three cells each extending to the level of the loading platform and one row to the outlets of which packing and weighing machines are secured. The cement is conveyed to the silo, where it is elevated and distributed by a bucket elevator and screw conveyors. At the bottom of the larger cells discharge doors and chutes are provided, by means of which the cement is conveyed to an elevator, which discharges into a conveyor leading to the smaller hoppers beneath which the packing machines are placed. The building in which the elevator and stairway are placed is constructed in timber and is independent of the silo structure itself. The arrangement of the cells and conveying plant in this warehouse permits of a thorough mixing of the contents of any cell by continuously drawing the cement from the bottom and returning it. The possibility of being able to mix the contents of a bin is a point distinctly in favour of a storage plant, as any variations in the character of the contents can be equalised in this manner.

The material most usually employed at the present day in the construction of cement warehouses on the silo principle is ferro-concrete, but brick and steel, timber and steel, and steel alone are also employed. The choice of material will naturally be governed to a large extent by their prices delivered on the site.

Automatic sack and cask packing machines are most economically employed in conjunction with self-emptying bins, and thus it occurs that in the cement trade they are rarely employed in this country. When they are employed, the cost of loading cement is materially reduced, and the saving in this direction must be credited to the cost of erection of a silo which is materially higher than the open bin system. For description of these automatic filling and

weighing machines reference should be made to an earlier chapter (pp. 155-160).

With open bins an average gang of packers can load—that is, fill, weigh, run into trucks and tie—150 to 200 bags per man in nine hours, while with automatic fillers the output per man is considerably greater, and the cost of loading correspondingly less.

The appliances used for shaking cement down in the casks depend for their satisfactory operation upon their ability to give a direct vertical motion with rapid alternations in direction to the cask. An innumerable variety of devices suitable to these requirements can be imagined and only one

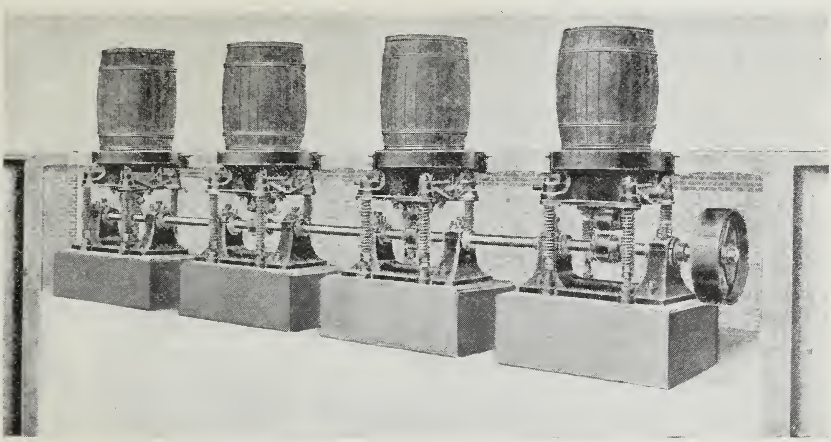


Fig. 145.—Cask-Shaking Machines (Lüther).

or two of the most commonly employed will be mentioned. The machine constructed by Krupp consists of an iron platform secured to a plank which is fastened at one end by holding-down bolts to a concrete block. Beneath the cask platform a toothed wheel held in bearings is arranged. This wheel engages with another similar wheel secured to a lay shaft provided with fast and loose pulleys. When this shaft is rotated the platform is moved upwards and downwards, owing to the wheels "bottoming," the plank acting as a spring.

Another machine has the platform held down by means of four spiral springs, and beneath the platform a roller is

situated, and the jigging motion is conveyed by means of a double cam secured to a lay shaft arranged below the machine, as shown in Fig. 145. These shaking devices are sometimes arranged on carriages so as to be easily moved from place to place; in such cases they are most conveniently driven by motors.

A machine which renders it possible to give the cask and its contents blows of differing strengths is illustrated diagrammatically in Fig. 146. The platform in this case is rectangular and is secured at one end to a shaft supported in bearings, and to the opposite end a pallet is secured which while the machine is in operation is in contact with the toothed wheel B. This wheel is secured to a shaft which is rotated, and the platform is thus alternately raised and

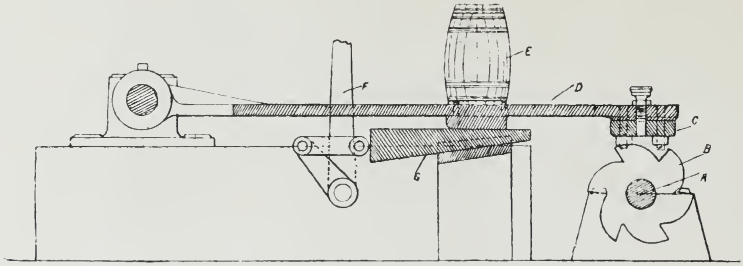


Fig. 146.—Lambert Cask-Shaking Machine.

lowered in rapid succession. The machine is put in or out of operation by means of the wedge G which is actuated by the lever F. By drawing this wedge out to a greater or lesser extent the shocks on the cask are correspondingly increased or decreased.

In connection with the cement warehouse a sack-cleaning plant should be provided. The condition in which the bags are returned by customers, especially the smaller ones, is usually extremely bad. Frequently they have been used for gypsum, lime, or material which it is even more undesirable to get mixed with the cement. The matter most usually adhering to the sacks is set cement. The cleaning of the bags is a matter of no great difficulty or expense if suitable mechanical appliances are provided.

The sack shaker illustrated in Fig. 147 will usually suffice

to remove any adherent material. It consists of a cage formed of an iron frame to which slats are secured. This cage is supported by trunnions journalled in bearings secured to a timber frame, or to iron standards, and is slowly rotated. The whole machine is enclosed in a timber casing provided with a hopper bottom, and access is had by means of a door. The sacks to be cleaned are put in the shaker in batches, one of the sides of the cage being made removable for this pur-

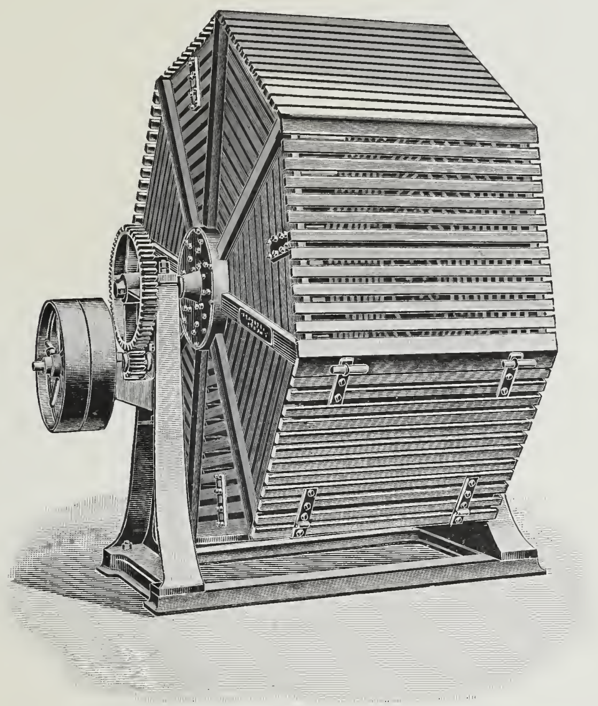


Fig. 147.—Sack-Shaking Machine.

pose. After replacing the cover and shutting the door of the casing, the drum is rotated and the bags are thoroughly shaken.

For use in cases where the material is so firmly adherent that it cannot be dislodged by the sack shaker, a machine in which the sacks are subjected to a thorough beating by being passed under a rapidly rotating spindle to which flexible beaters are secured may be employed. The wear on the sack is greater with this type of machine than with the sack shaker,

and it is usually employed only when the shaker is unable to turn the bags out sufficiently clean.

The above machines are naturally very dusty in operation, and consequently are usually connected with a dust collector. A complete sack-cleaning plant is shown in Fig. 148, and, as will be seen, it consists of a sack beater and sack shaker connected to a suction dust collector by way of sheet-iron exhaust

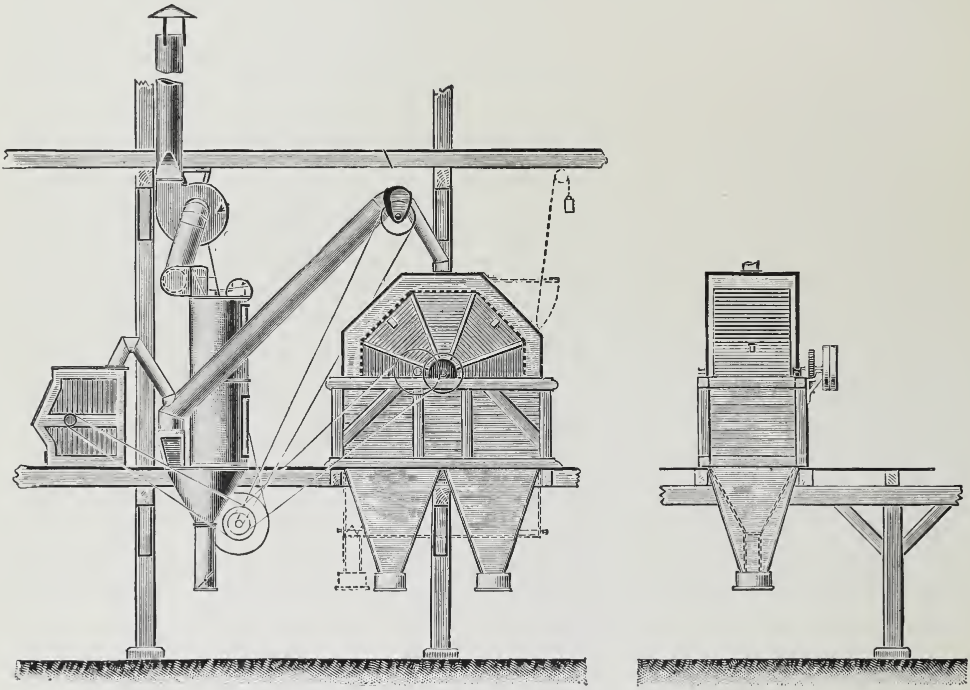


FIG. 148.—Complete Sack-Cleaning Plant, with Dust Collector.

trunks. A similar plant situated at the end of the cement warehouse is shown in Fig. 141. In this case the hopper bottom of the sack shaker is connected by means of a screw conveyor to an elevator which discharges the dust into a hopper-bottomed bin, which also serves as an expansion chamber. The connection between the casing of the sack shaker and dust collector is made by way of it, suitable baffles being provided.

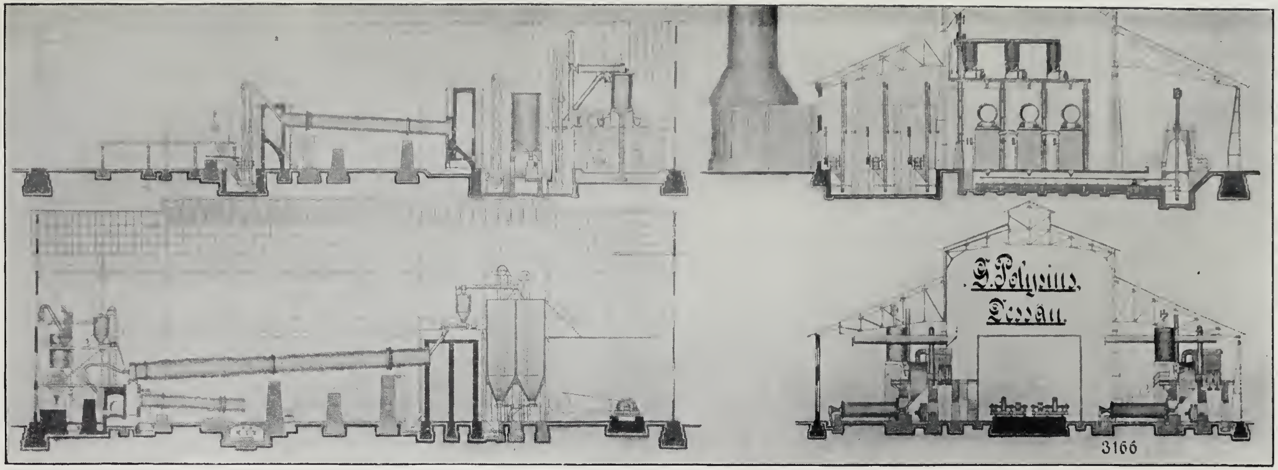


Fig. 149.—Section of Cement Plant Working on Dry Process.

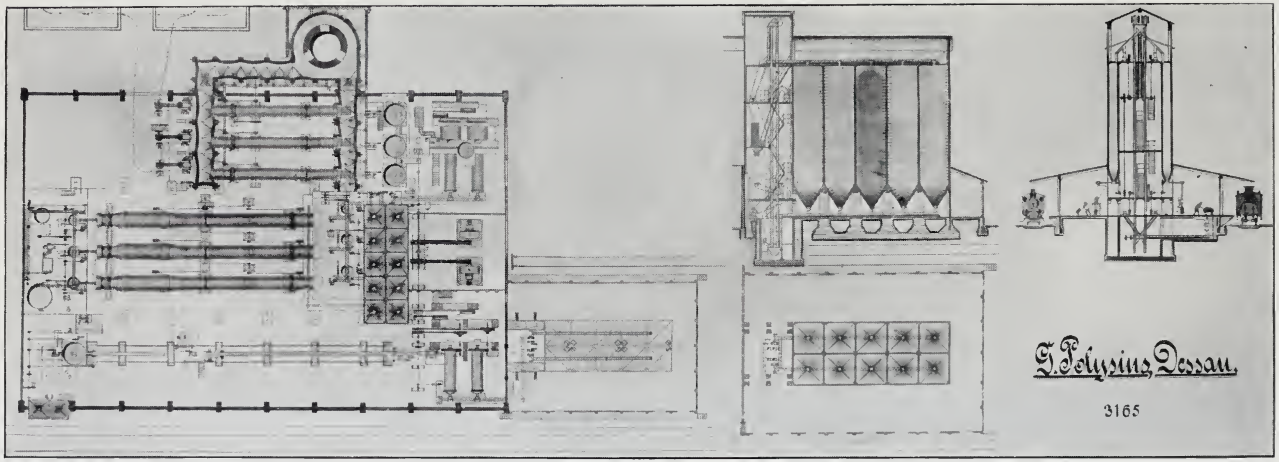


Fig. 150.—Plan of Cement Plant Working on Dry Process. Also Section of Cement Silo.

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CHAPTER III

DESCRIPTIONS OF SOME MODERN CEMENT PLANTS

In Figs. 149 and 150 a cement works operating on the dry process is illustrated, in section and plan. The raw material is brought by an aerial ropeway to the crushers, from which it passes through the driers—heated by the waste heat from the kilns—to storage hoppers. From these hoppers the stone is taken, in proportions regulated by automatic weighers, and elevated to a mixing drum, from which it passes to the hopper feeding the mills. The raw mill consists of two Cementors and two tube-mills. The meal produced by it is taken to a ten-celled silo. From these cells the material is taken by means of double feed worms, and delivered, by way of an elevator and conveyor, into the small feed hoppers arranged at the feed end of the rotary kilns. From these hoppers, each of which is provided with double feed worms, rotated at variable speeds by means of a speed regulator, the meal passes to damping-troughs, and by way of water-cooled chutes to the kilns, of which there are three, each 42·7 metres in length, 2·1 metres in diameter, with burning zones 2·5 metres in diameter. The clinker from the kilns passes to the rotary coolers, and the air required for firing the kilns and for drying the coal is heated by its passage over the clinker.

The coal is passed through a drier and is ground in a Cementor and tube-mill; the dust being delivered into hoppers arranged above the burning platform. The coal dust feed is of the double worm type, with speed regulators and hot-air injection for the coal dust. The clinker from the coolers is taken, by means of shaking conveyors and elevators, to the storage floor alongside the kilns; and it is drawn from here to feed the cement mill, which consists essentially of two Cementors and two tube-mills.

The finished cement passes to a warehouse, provided with ten hopper-bottomed cells from which the cement is taken, as required, and conveyed to two packing cells, beneath which automatic sack and cask filling and weighing machines are arranged. Two loading platforms are provided, by means of which the cement is loaded into vans.

In connection with this plant, it may be remarked that the same chimney is employed for taking the gases direct from the kilns, or through the driers.

In Figs. 151 and 152 a modern rotary kiln plant employing the wet method of preparing raw materials is shown. The material is tipped from bogies into the wash-mills, of which there are four, arranged in pairs. From the first wash-mill of each pair it passes to a second, in which it is further reduced, and the coarse slurry then passes to the tube-mills in which the grinding operation is completed; the finished slurry passing to the mixers, of which there are eight, each of the triple stirrer type. When corrected and tested, the slurry passes to the small feed tanks arranged above the level of the kilns, and by way of an adjustable feed through them. The kiln and coal mill plant is similar to that just described for the dry process plant.

The plant illustrated in Figs 153 and 154 is most interesting, as it is one of the most recent plants to be erected, and it operates on the wet process; grinding hard raw material. To this development in the industry reference has been made in the early chapters, and the circumstances leading to the choice of this system or of the dry process have been discussed.

The crushed raw material is fed from a hopper together with water into the preliminary grinding-mill, a short tube-mill with steel-ball filling and called the "Rotator." The mixture of granular material and water passes to the Finitor, a steel-ball tube-mill, double as long as the preliminary grinding-mill. The finished slurry passes thence to one of the mixing tanks, from which, after adjustment, it is taken to the feed tanks and to the kilns. The clinker from the cooler is taken to the storage yard in bogies, or direct to the cement mill, which consists of two Cementors and two tube-mills.

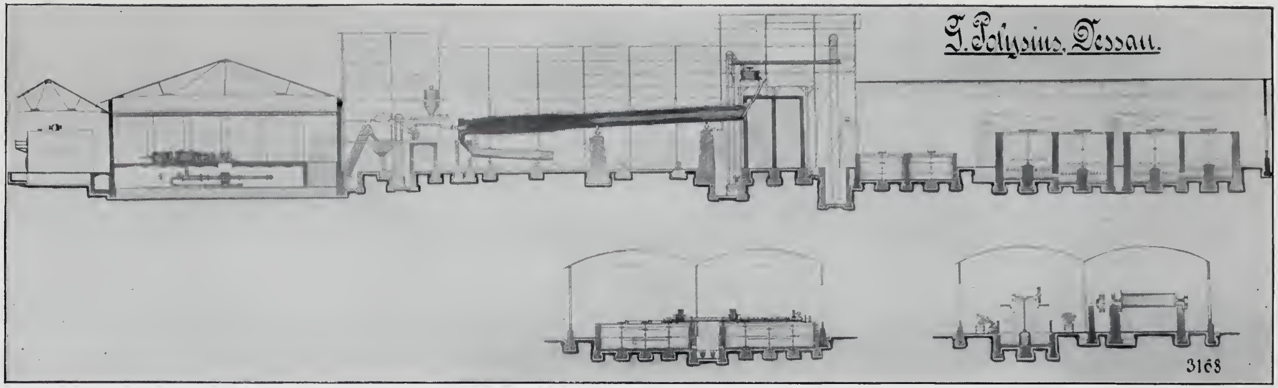

Fig. 151.—Section of Cement Plant Working on Wet Process (with Wash-Mill).

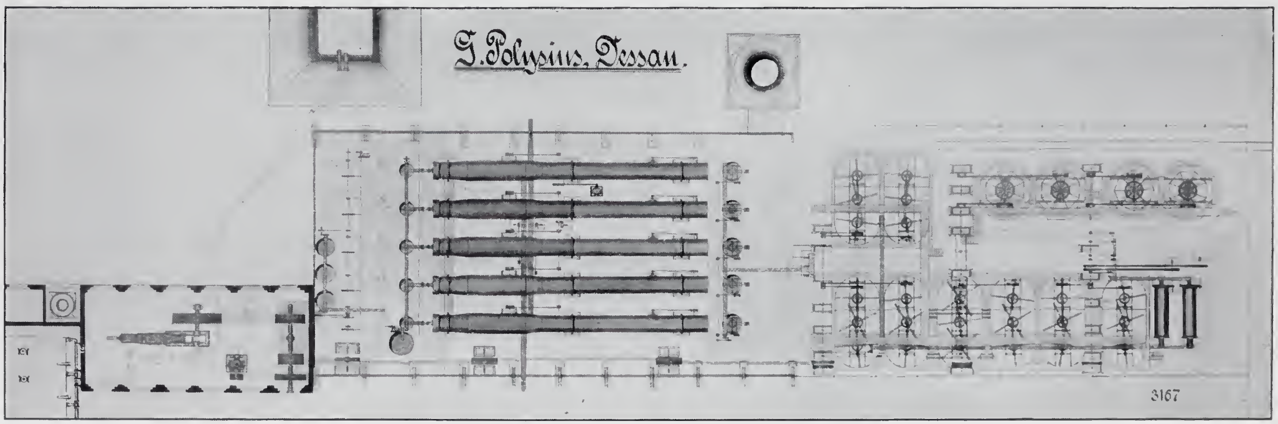

Fig. 152.—Plan of Cement Plant Working on Wet Process.

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Fig. 153. Section of Cement Plant working on Wet Process, employing Short Tube-Mills and Tube-Mills for Grinding Moderately Hard Raw Material.

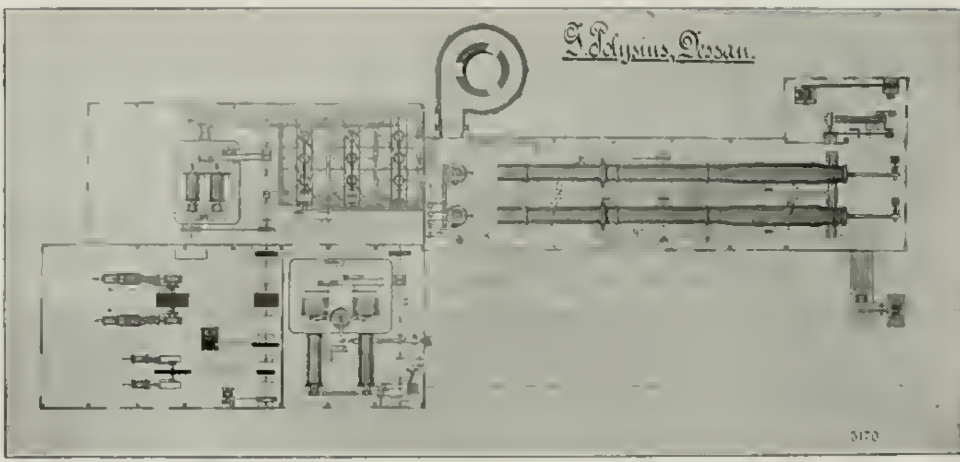

Fig. 154.—Plan of Cement Plant using Moderately Hard Raw Material prepared by Wet Process.

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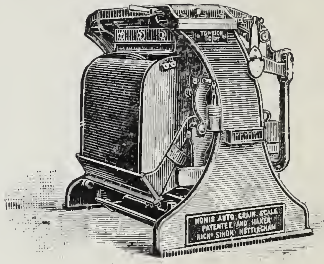

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